

DYNAMIC VISUALIZATION:

**The Significance of Motion in the Visualization of the
Architectural Design Model**

by

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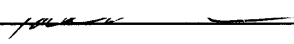
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Submitted to the Department of Architecture on May 9th, 1986
in partial fulfillment of the requirements for the degree of
Master of Science in Architecture Studies.

ABSTRACT

The visual expression of architectural ideas, specifically in the preliminary stages of design, has generally been by means of static images on two dimensional surfaces. Our perception of a building or an urban context compared to what actually is communicated by most visual tools, indicates to us that most representation media lack an essential quality, that of movement. Not until recently were we able to introduce this quality within our methods of representation. Computer graphics as a new tool for visual expression can provide us with the means to examine spatial ideas dynamically. This can increase an observer's understanding and enable designers to manipulate their ideas in a more reactive and dynamic environment.

This thesis will examine the more conventional media used to convey form and space, and discuss the advantages and disadvantages associated with them.

The central issue to this thesis is the aspect of movement; that motion is an essential part of spatial understanding and that of visual perception. As a base for my arguments I have chosen some theories of perception relevant to architecture, and tried to find parallels which could give rise to a better understanding of architectural form and space and to it's representation.

Finally, I have looked at the state of the art in computer graphics; the difficulties involved in creating computer images, how they are being overcome and lastly the potential for visualization that computers can offer in the future.

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DEDICATED TO MY PARENTS. MAHIN & GODRATOLLAH TASHAKORI

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INTRODUCTION

A great deal of discussion concerning the significance of architectural representation, has led us to an increasing awareness of the importance of the way architectural form and space are visually represented; what qualities each type of representation is capable of communicating, and if the means constitute the end, how efficient are the means.

Each era has given birth to new forms of representation. For example; during the Renaissance perspective became the method without which the concepts of the period could never have been developed.

This thesis will examine the media involved in the design of space and form, and look at the advantages and disadvantages associated with each of them. Although there are many factors influencing the outcome of an architectural design, (such as the ideological issues which form architectural thought) the focus will be on the visual tools which give shape to ideas.

The reduction of certain qualities is inherent in the process of representation. This leaves the designer to choose the visual tool that will convey the qualities he feels are most significant. This can prove to be valuable in the world of fine arts, but the architect who hopes to see an objectified fulfillment of his concept, knows that the representation is

not an end in itself. It is the completed structure that will be the ultimate realization of his concept. Therefore the desired tool is the media that will most accurately produce the intended environment, not necessarily the proposed concept.

The central issue of this thesis is the aspect of movement; I will argue that motion is an essential part of spatial understanding and that the experience of architecture as a three dimensional object is a perceptual occurrence involving movement. Architecture comes into existence through an infinity of individual and active impressions, which create its total image.

The basis for my arguments rest on the theories of perception relevant to architecture. In order to provoke a greater interest in the understanding of architectural form and its representation, I have attempted to find parallels between the process of perception and the representation of architecture. These theories are generally overlooked by architects, but a more detailed examination of these theories may indicate new possibilities if we adopt new techniques for analysis and the illustration of urban and architectural phenomena.

Our generation stands under the banner of computer technology - a symbol of our era. Computers have permeated almost every walk of life. Yet they have not found a major niche within the architectural field, computers are not

considered an acceptable design solution. One reason is the intimidating aspect of these computers, they are not user-friendly enough. Drawing on paper still comes more naturally than translating an image onto the screen.

A closer look at the state of the art in computer graphics can illustrate some of the advantages if the systems could be geared to a less sophisticated operator. As an instrument of visual expression, a system with movement capability could be to our era what perspective was to the Renaissance.

The problems related to image synthesis will be discussed; How these problems are being dealt with and what is expected in the near future, along with some examples of projects by architectural firms involved with computers, specifically computer generated imaging.

"The process of understanding visual phenomena, or visual thinking, characterizes both the experience of the seen world and the artistic invention of new experiences. Both are ways of seeing metaphorically in order to understand and communicate. But perceptions change according to the particular place and historical moment, and just as intellectual history is characterized by differing styles of thought, visual thinking is tied to cultural change."

Gilbert Cass

ISSUES IN ARCHITECTURAL REPRESENTATION

Architects are constantly simulating objects and environments because of their need for visualization and explanation. Models, perspectives and plans make up the bulk of an architects representational devices. This creates a problem of inadequacy, as the simulations often fall short when measured against the experience of the final product. Plans have their own language and are therefore difficult for laymen to interpret. Perspective views are by nature selective because the architect chooses the most complimentary views and images for what he feels can best communicate the intentions of the design. i.e. what it should look like. So on the one hand you have an architect full of hope that his presentation can convey some sense of what will eventually be a reality; and on the other hand you have a presentation that can be misleading.^{1.1} Under these circumstances it is surprising that more substantial information is not required before a project is approved.

HISTORY

1.1

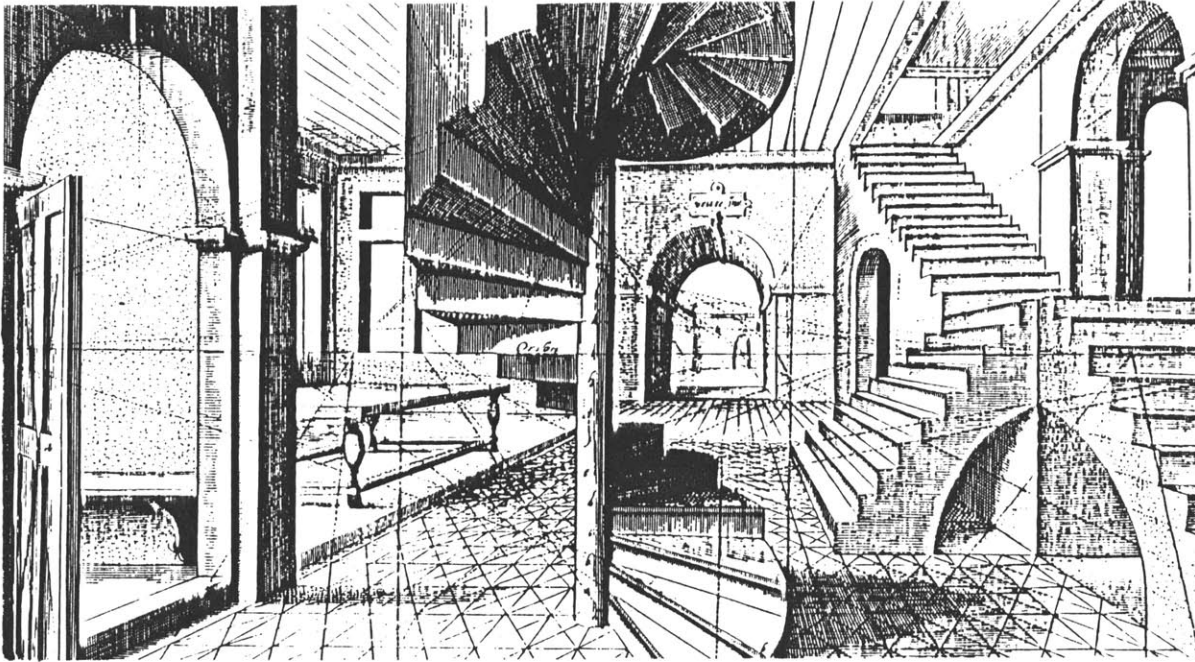
The nature of the 'language' of architecture is so specific that it creates barriers which prevent it's understanding by laymen. The abstractness of environmental media, plans, renderings and elevations that architects use to convey their

designs, do not by themselves encourage comprehension by an untrained public; (in some cases the designer is also deceived by these representational forms.) Until architectural representations can be displayed in a more self-explanatory manner design decisions will be kept selective and will exclude public opinion.

The medieval architect would make a laborious study of examples of buildings. The research would include measuring the proportions of particular aspects, so as to accurately reproduce them in his building. The introduction of the scale model enabled the architect to convey his intentions and to determine the cost of the project. The end of the Gothic period saw the architect constructing models of parts of buildings, possibly for testing purposes.

As the Renaissance architect was inspired by the Graeco-Roman period, in order to test the practicality of his more dynamic proposals, he had to construct working models. Often using the very materials intended for the building. Elaborate models were common practice. These were useful tools for visually coordinating mass and space.

With the gradual separation of art and architecture the architect committed himself to an intellectual perspective on design, leaving the fine artist committed to 'art for art's sake'. This new outlook on design became seated in the need for developing skills and conventions for drafting space. As a result, the architects primary concern was how to draw the

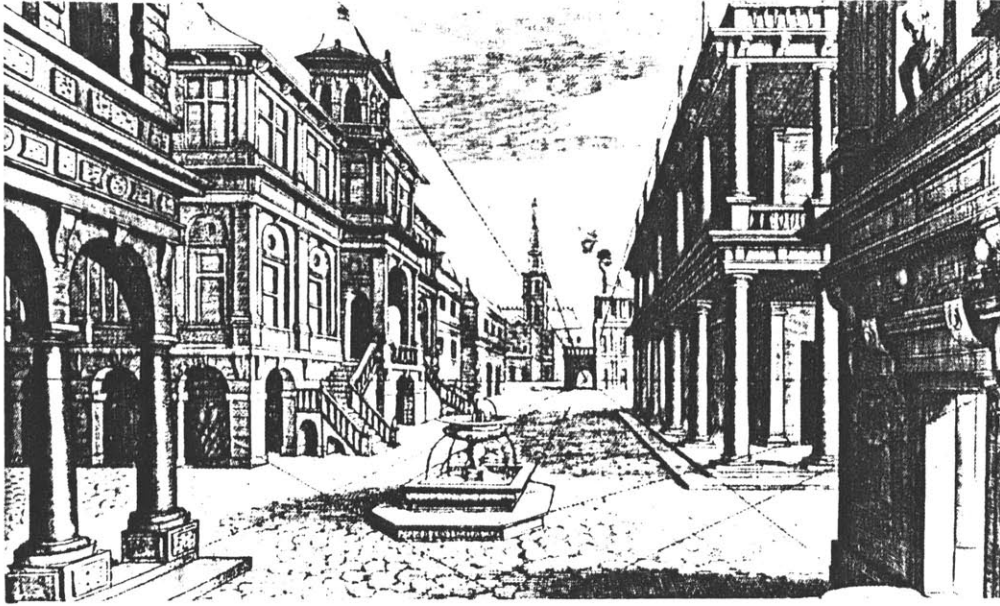


1.1 Perspective figure from Vredeman de Vries,
Artis Perspectivae..., 1568

building - instead of what to draw. This was not always the case, it was customary to strive to portray the experiential qualities of an environment. Architecture was becoming more and more affected by methods of depiction. Methods that would affect the structure of ideas and predestine the outcome of the architecture.

The innovation of perspective led to a shift of emphasis towards two dimensional representations. This, in turn, started a fad for drawing buildings and even entire cities as visionary images.

Brunelleschi's contribution to perspective had the architect on the outside of his image; By saying there must be distance between the viewer and the object. The word, per.spective.



1.2 Vredeman de Vries, "Imaginary City" from Perspective-
The Most Famous Art of Eyesight, 1604

from the Latin, literally means through seeing. Essentially it means the drawing is a window. The concept of looking into a drawing was not universal. Oriental art uses a reverse perspective with lines radiating out and away from the viewer. This allows the artist to visualize from inside his image.^{1.2}

Brunelleschi's perspective was contrary to the nature of perception because it required the viewer to freeze in time.

The development of linear perspective during the Renaissance, was due to an extraordinary combination of sense experience and mathematical abstractions. Principles of perspective that we take for granted, such as diminution; that an object will appear smaller in relation to its distance; and foreshortening, were all elementary awarenesses which were brought into a system at that time. This system soon

dominated the pictorial presentation of the visual arts, including architecture. Linear perspective had gained such a controlling hold over the visual arts, that any deviation from the norm was regarded by even the most naive viewers as unnatural and distorted.^{1.3}

Due to the restrictive nature of one point perspective, the post-renaissance painter, experiencing the world, is located in one defined view point. This constrains the viewer to share this point of view also. "The architect on the other hand, does not have such a station point, ... one does not physically and aesthetically experience a building simply by looking at it -perhaps least of all by looking at a facade, because the facade very often most resembles the plane of a painting - one experiences it by being in it, living in it, being a part of its reality."^{1.4}

MOVEMENT AND ARCHITECTURAL SPACE

1.2

"The look of a building when seen close at hand is one thing, on a height it is another, not the same in an enclosed space, still different in the open." Vitruvius

For the most part, we perceive an architectural space as a sensory occurrence involving movement, for as we proceed through an environment we experience a myriad of changing sensations, each takes us from one spatial impression to another.

"The history of articulated space, the special space conceptions of different periods, have been determined by the grasp of one, two, three or more dimensions.

The magnificence of the Egyptian temple could be comprehended by walking through a basically one dimensional straight line, the sphinx alley, leading towards its facade.

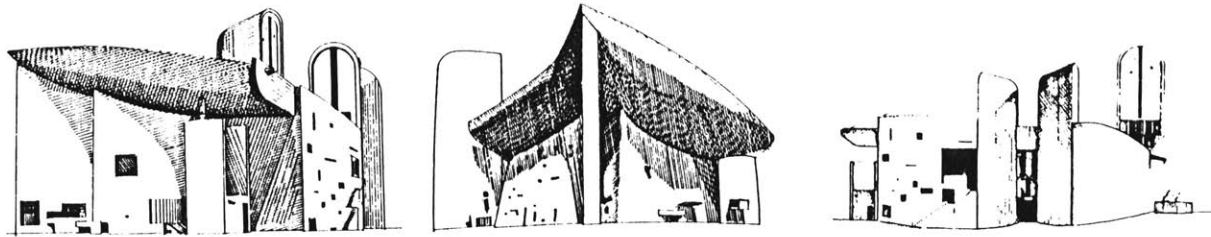
Later the Greek architects of the Acropolis designed a two dimensional approach to the temple so that the visitors had to move through the Propytaen, between the Erechteion and Parthenon, around the colonnades toward the main entrance.

The gothic cathedral also applied this concept most intriguingly to the interior. The spectator was placed in the midst of the nave, balcony and choir, and became the center of coordinated space cells of all directions.

The Renaissance and the baroque brought man into closer contact with the inside and outside of the building. Apart from the hanging gardens of Semiramis and the moorish-spanish architecture, these were man's first attempts to integrate building and nature, not merely fit building into its surrounding.

In our age architecture is viewed not only frontally and from the sides, but also from above - vision in motion. The birds eye view, and its opposites, the worm's and fish-eye views, have become a daily experience. Architecture appears no longer static but, if we think in terms of airplanes and motor cars, architecture is linked with movement."^{1.5}

The visual experience of an architectural setting comes into existence through an infinity of individual impressions and visual projections. Moving towards and around a building or going through its interior, is what gives the observer the total image of a particular architectural scene or object. The total image being a sequential composite of all the perceptual impressions received by the viewer. The order of perceptions put into effect by a viewer's passage from one room to another is as authentic a quality of architecture as are the static array of spaces. Although the percept of simple forms such as a cube or a cylinder can be easily



1.3 Le Corbusier. Notre Dame du Haut, Ronchamp: Three views.

understood in their totality, without having to experience all of their different angles and views; When a building is structured in such a complex way that it cannot be broken down into simple geometric forms, one particular viewing point would make it impossible to distinguish the shapes attributed to the physical structure and those created by perception. As an example, there is almost no angle from which to photograph Le Corbusier's chapel at Ronchamp that will capture it's shape;^{1.6} One has to encircle the building to verify its form. So in a case such as this, a full mental image can only be attained through a wide range of projections.

In an essay written by R. Arnheim, he compares the temporal qualities experienced in architecture to those found in music, dance and film. He argues that although architecture as an object, exists in space outside of the time dimension, the experience of it is an event or a happening occurring in

time; similar to that of dance, music and the film. This dispells the belief that "architecture is born within the confines of a sheet of paper;" But there are aspects particular only to architecture.

For example, as an observer of a dance or the listener of a piece of music, one experiences them from the outside, never becoming a part of it; but in architecture the viewer is the actual participant, moving through it's spaces.

Another difference distinct to architecture is that as a sequence in time the appearance of it's components are transformed; a specific order for viewing can cause a part of a building to exhibit several outward appearances. As an observer alters his position in an architectural sequence, he causes a change in the appearance of all the parts of a building.

The other difference worth mentioning, relates to the connection between the order of a sequence and the overall circumstances that creates it. In architecture "...the experience of traversing the building must be firmly embedded in an image of the building's spatial totality because the sequence makes sense only as an aspect of the building's timeless being."^{1.7} It is important to get a cognitive map of the whole through an ordered sequence of impressions, in order to understand and appreciate a building, whereas in film one can have several unrelated shots creating a sequence.

"It is aesthetically indispensable that viewers become aware of the interplay between timeless spatial structure and the time-bound avenues through the building. Certain churches of the late baroque, for example, can be understood as works of art only when the various sequences and perspectives are perceived as fitting the total structure in a way that is most clearly visible in the building's ground plan. The remarkable order of the skeleton is the indispensable counterpart of the perturbing complexity of the directly given particular sights. It is true that in music also, the listener must fit the elements of a composition to an image of the whole, but in music the whole structure is sequential, as are the parts. The interplay of exploratory action and timeless being is characteristically architectural."^{1.8}

Thus we can conclude that it is the perceptual experience of a structure through movement that will lead us to a fuller understanding of architecture. In recent years, perceptual theorists have sought to persuade us that the line between the perceiver and the object is a formidable one and the perceptual process is more than just cognitive acknowledgement of detached objects, but that the perceiver is an intricate part that leads to the success of the perceptual process.

FOOTNOTES

- 1.1 D. Appleyard, Visual Simulation in Environmental Planning and Design. 1979 p.1
 - 1.2 Tom Porter, How Architects Visualize. p.7
 - 1.3 Wolfgang M. Zucker, The Image and Imagination of the Architect. p. 73
 - 1.4 Rudolf Arnheim, "Buildings as Percepts." p.17
 - 1.5 L. Moholy-Nagy, Vision in Motion. p.244
 - 1.6 Rudolf Arnheim, "Buildings as Percepts." p.16
 - 1.7 Ibid. p.15
 - 1.8 Ibid. p.17
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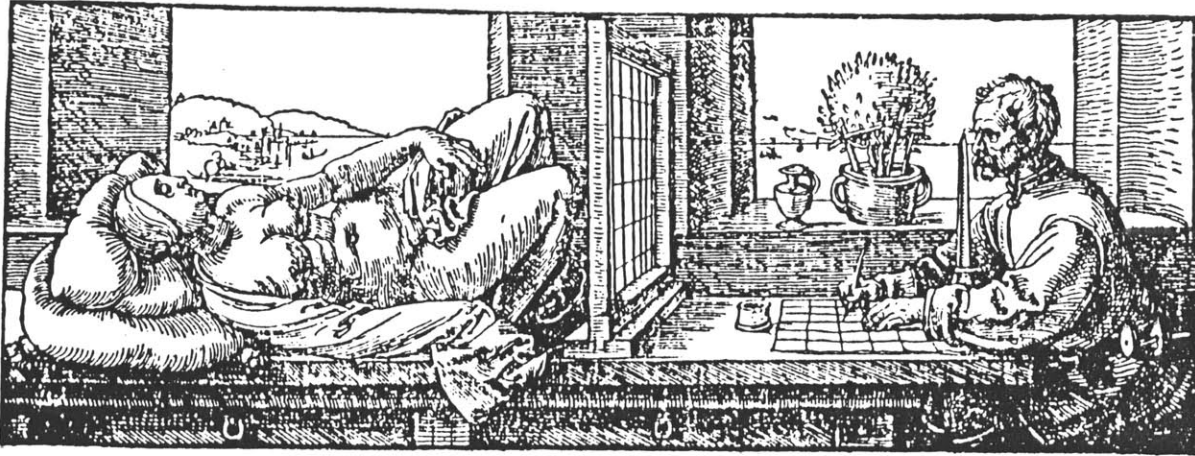
VISUAL PERCEPTION

Is what you see what you get? Does the way we visually experience a structure determine the degree of understanding? Both these questions are dependent on what is inferred by visual perception. We know perception is more than a sensory experience because it relies on intelligence and the ability to rationalize between possible solutions to perceptual discrepancies.^{2.1}

In order to experience the totality of an architectural object or urban environment, to understand the many essential properties involved, it would be necessary to delve into the visual issues concerning the theories of perception and those of architecture. Although there are many conflicting theories about how we perceive what we perceive, for the most part, my arguments are based on the perceptual theories of J.J.Gibson and Julian Hochberg; because their theories are most applicable to the representation of architecture. Their work enables us to analyze and examine the properties existing in the perception of form and their relation to the media of architectural representation. With this, we can move to the issue of how we may most fully represent architectural form and space.

Experience can be broken down into first and second hand experience. In first hand experience the individual becomes aware of something, in second hand experience the individual is made aware of something. First hand experience and its process is what we refer to as direct perception. The process of second hand experience is much more complex and it involves the action of a second person upon the perceiver. This double stage process requires a vehicle to convey perception indirectly; Language is the primary means of such awareness. But pictures and models may also serve to convey indirect perception.

The most recognizable feature of perception is that it varies under differing circumstances. Our percepts enable us to distinguish among specific features of our physical environment for the purpose of recognition. Through this discrimination we identify objects, places, and events when we are confronted with them again. Learning is basically a process of discriminating and identifying through sensitivity to the appropriate stimuli and answering with the appropriate response. In order to communicate a second hand experience one must provide an acceptable substitute for the specific situation. The use of additional substitutes other than words, has often proved beneficial to assist someone in successfully discriminating and identifying situations.



2.1 Durer's Version of Alberti's Veil.

SURROGATES AS REPRESENTATIONS

2.1

The term surrogate is defined by J.J.Gibson as "a stimulus produced by another individual which is relatively specific to some object, place, or event, not at present affecting the sense organs of the perceiving individual."^{2.2}

To clarify the above statement; A surrogate is not a 'substitute stimulus' or a 'conditioned stimulus'. Snow is not a surrogate for cold weather, or a window is not a surrogate for light. These are simultaneous occurrences of physical events only, merely signs. Signs represent objects and events and conditions other than themselves. Unlike surrogates, signs are used to elicit and formulate behavior.

"The specificity of surrogates to other referents is analogous to what was called an obvious fact about direct perception, that is, that it is different for different physical things. We assume that direct perceptions

correspond to realities, or rather that they come more and more to do so as the perceiver learns."^{2.3} With this in mind our main concern is how surrogates can arbitrate or regulate our perceptions and still be equal to our surrounding reality; Keeping in mind that the psychological state of the producer can have bearing on the precise intention of a surrogate but that the surrogate itself cannot convey emotive or expressive signs, or transfer any other reaction specific to the psychological state of the producer.

We can list two fundamental motor acts which constitute and produce surrogates. These are 1. drawing, painting, and in extreme cases writing (such as Heiroglyphics.) 2. Shaping substances through molding, cutting, or fitting pieces together; This includes sculpture and all physical models. In secondary surrogates, which result from more complex operations, (usually mechanically aided) the producer has less hands-on involvement. i.e. photography, or cinematography; Primary surrogates can be classified as man made, secondary surrogates, machine made. thus an artists renderings represent a primary surrogate, while a photograph is a secondary surrogate.

Surrogate making is dependent on self stimulation. Stimulation feeds into a producer simultaneously with his action. For example a draftsman sees the movement of his own pencil while rendering; The perceptual process and the surrogate making process lead into each other and the two

become intertwined. The same would be true of sculpting, yet the end results are different. The medium influences the outcome. For example when working with clay (for model making) the individual becomes more involved with the actual total form being created; while drawing on paper, the relation of elements, and/or configuration of detail becomes the issue. For architecture what medium can bring the architect's representation closer to the actual building will prove to be of utmost use in design.

There are two polar cases of surrogates; Those created by convention and those created by projection. Language or mathematical symbols tend to fall under the conventional surrogates; an architectural example would be a plan. Models pictures and motion pictures are related to the category of projection. "The object and its name have an extrinsic relation whereas the object and its picture have an intrinsic relation."^{2.4} It is theorized that nonconventional, projective, or replicative surrogates have the capability to become more and more like the original until neither are distinguishable from the other. In visual perception, a model under specific viewing guidelines can be improved upon to the point that it is no different than what it is supposed to be representing. Under severe guidelines a motion picture might be altered leading the viewer to believe that he is seeing a realistic situation and not an enactment. Conventional surrogates do not offer this characteristic. We can make the following assumptions from the above statement.

1. Pictures and models give a more efficient representation of direct perception than words or symbols can.
2. Projective or replicative surrogates are less capable of referring to abstractions, the referent is usually physical.
3. There are also what we will refer to as mixed surrogates, which incorporate qualities of both conventional and projective surrogates; For example chinese characters which retain both the fidelity of a picture and the characteristics of a word.
4. When we introduce graphic symbolization into a picture we sacrifice the picture's ability to represent (in full). In trying to gain abstractness the picture loses its concreteness. Thus we can conclude that mixed surrogates can not share the extreme qualities of something abstract and something concrete at the same time.

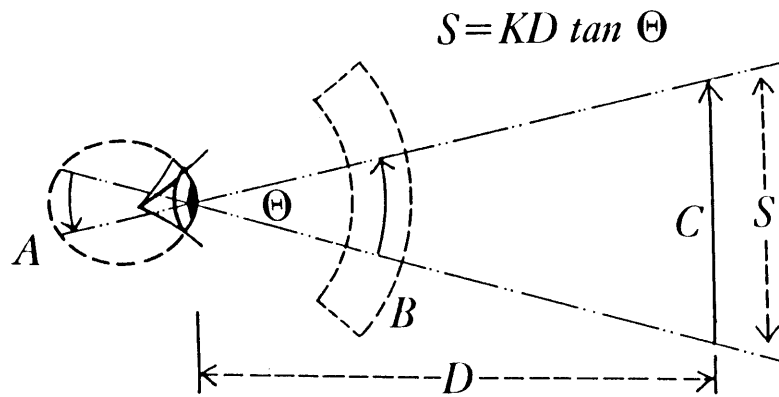
The construction of working models that replicate movement and the course of events which can simulate total situations, are difficult to fabricate, (they could go on indefinitely in terms of detail) and are not economical. If a model is needed to serve only as a visual surrogate, a more practical solution would be pictures, or motion pictures, as long as you can limit the perceivers view to one position.

A model retains loyalty to the referent on many levels, such as shape, proportion, color, texture, etc. It is not always necessary to recreate all the attributes of a model in order

to learn to utilize it. As for architectural models, what properties of fidelity need to be simulated, will be discussed in later chapters.

"A faithful picture is a delimited physical surface processed in such a way that it reflects (or transmits) a sheaf of light rays to a given point which is the same as would be the sheaf of rays from the original to that point. This definition is intended to apply to paintings, drawings, color prints, photographic prints, transparencies, projected slides, movies, television and the like when taken as cases of pure representation."^{2.5} Thus we understand that a picture is a projection of a three dimensional body onto a two dimensional surface. The fidelity of a picture is dependent on the degree of accuracy to which the tonal composition of the referent is reproduced. Yet another important property for pictures is scope; It applies to a picture's boundaries and how a flat surface is visually limited by its edges. Panoramic views and holograms are some of the efforts to overcome this limitation. Scope can affect a viewers perception of the subject through discriminatory representation; Scope can bring a viewers attention to focus on desirable characteristics of a scene that a producer feels merit scrutiny.

When viewing a picture there are two distinct types of perceptions occurring simultaneously; One is the mediated perception recieved through the picture, the other is the



2.2 Hochberg, "Visual Perception in Architecture".

direct perception of the actual picture's surface itself. Put simply in the act of viewing, you receive information on two levels, one is the awareness of your physical surroundings, the other, is the experience of a proposed environment.

THE RETINAL IMAGE

2.2

The perceptual process, and how we perceive the physical world, begins with the image of the object or layout on the retina, which is the light sensitive tissue area at the back of the eye. Only a fraction of the retina, called the fovea, is specifically sensitive to small details; In order to capture all the details of a scene or an object of normal size, the eye must be continuously moving.

An optic array is defined as the pattern of light provided by the scene to the eye. As Hochberg explains in his book, Perception, the retinal image is a composite of the pattern

projected by the optic array, and the actual physical direction of the eye; i.e. what the eye is focusing at within the array. The optic array and the retinal image are both two dimensional by nature and consist of patterns of light energy. That this interface takes place without the need of any three dimensional aspects, is the most important point of perception relating to architecture and other visual media.

A three dimensional object or scene can be successfully replaced by a flat picture, mural or other such two dimensional surrogate. If both scenes create the same optic array only from one specific viewing position; A slight movement can reveal to the observer the two dimensionality of the surface. The procedure for creating such surrogates, was first implemented during the Renaissance by artists such as Leonardo da Vinci and Brunelleschi. Alternatively, when confronted with actual physical depth, the viewer may not necessarily choose to take advantage of his allowed mobility, and thusly will deny additional information that the space would convey. At this time the architect should undertake to design a space that by its physical structure would delegate the pathways of viewpoint and the desired rate of view;^{2.6} In this way would the architects intended perception of the space be realized.

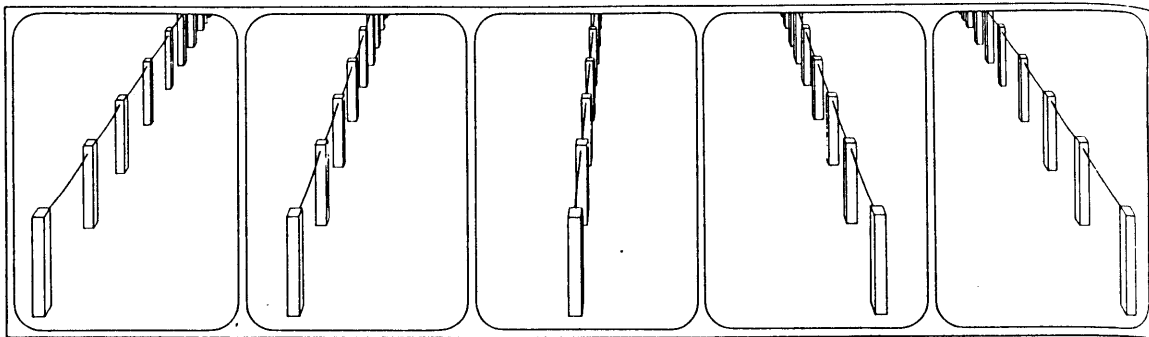
FOOTNOTES

- 2.1 Although ideological issues and what we learn to see do effect the perception process, for the purpose of the paper I have concentrated mostly on the perceptual process as a discrete phenomena rather than personal understanding of objects.
- 2.2 J.J. Gibson, "A Theory of Pictorial Perception." p.93
- 2.3 Ibid. p.94
- 2.4 Ibid. p.93
- 2.4 Ibid. p.99
- 2.5 Ibid.
- 2.6 Julian Hochberg, "Visual Perception in Architecture." p.28
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THE VISUAL SENSE OF SPACE

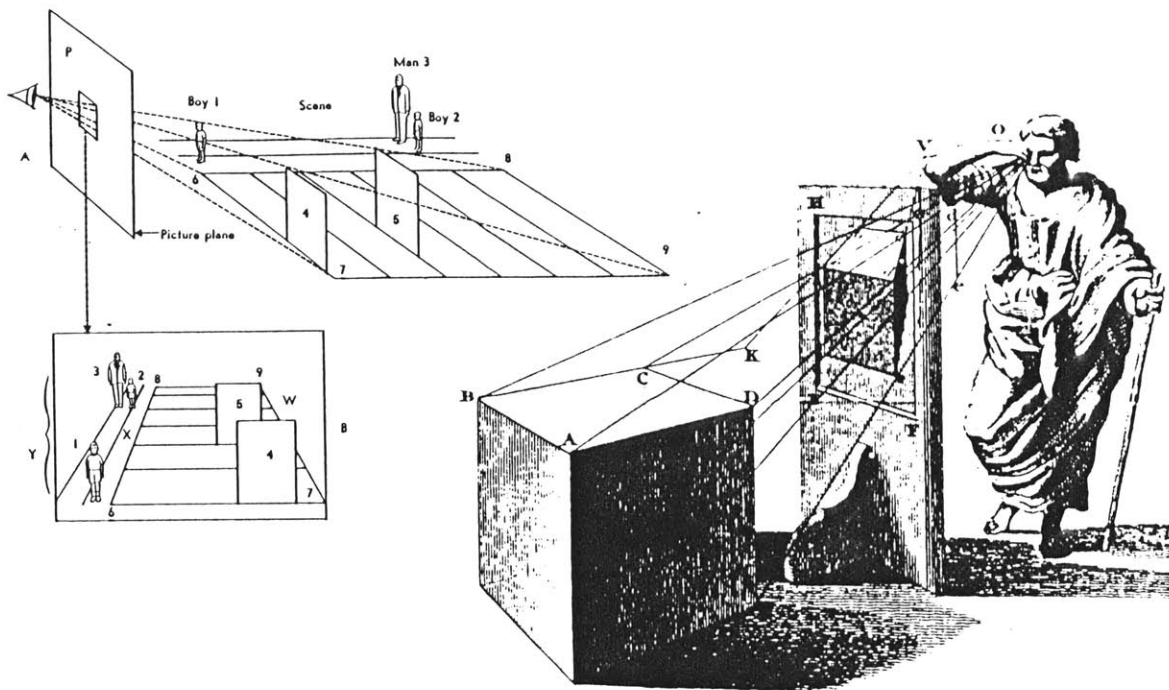
Man's visual sense of space is dependent on an ordered system of optical functions, set off by visual contact with the physical world. These functions or cues enable the observer to better understand space. This information can be useful to help architects understand how representations may work, and promote research into more definitive methods of representation. Pictorial depth cues are the clues given in any pictorial representation, which enable the static viewer to better comprehend the space depicted. They are depth informations about real space. For example, in linear perspective one gets a stronger impression of depth if the texture/density distribution and triangularity of parallel lines converging in depth are depicted accurately according to their referent. Conversely if such pictorial depth cues are replaced by misleading angles and texture distribution, even a three dimensional space would be misinterpreted for a flat surface.

One type of visual cue which aids in our perception of depth is motion parallax. Motion parallax is an apparent change in the direction of an object caused by a change in movement. For example, if you were to walk perpendicular to a picket fence, you would observe an apparent shift in each post that gradually became less as your distance from the fence



3.1 J.J.Gibson, Perception of the Visual World.
An example of motion Parallax.

increased. The fence itself would also appear to get smaller.^{3.1} Along with being an example of motion parallax, this is a valuable depth cue because your movement past the fence allows you to confirm the three dimensionality of the fence, by showing all sides of it. The same holds true in an architectural setting. It is your movement past a building or through it which gives you the most information about the space; because your senses receive spatial information about the depth and relation of objects to their surroundings. In two dimensional static images this cue is not available. We must look to other methods to discern depth in two dimensions.

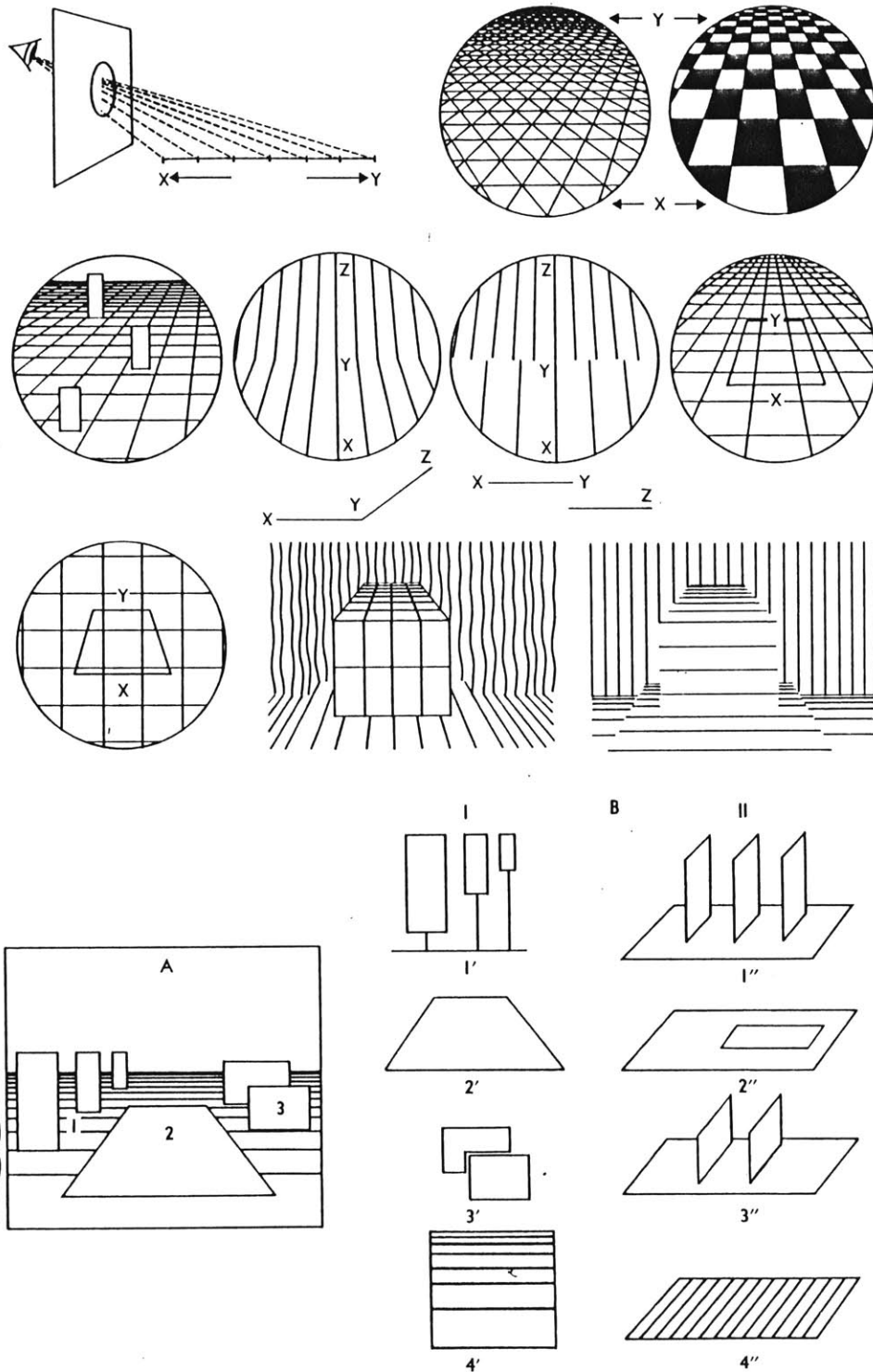


DEPTH PERCEPTION

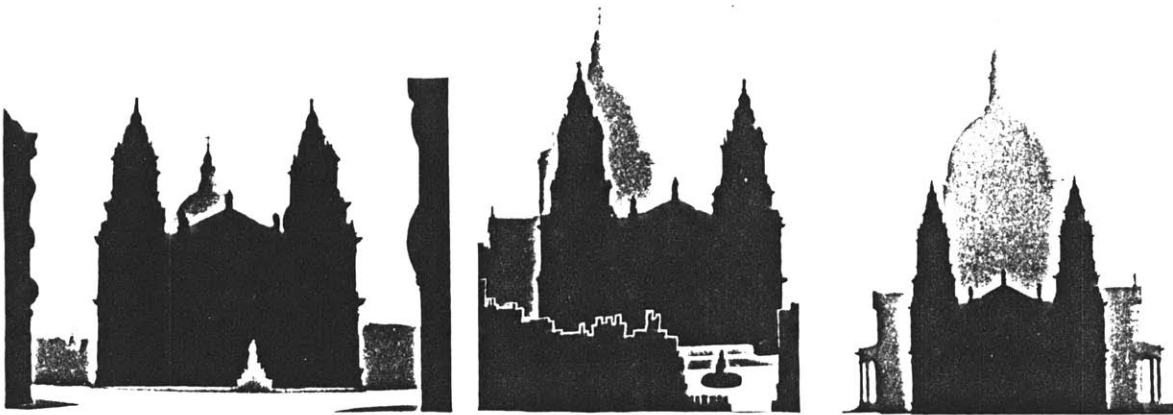
3.1

The architect is responsible for designing all differences in view that are brought about by the viewer's motion around and through a designated area. His primary concern should be the interface between the viewer and his world. This interface is referred to as a "vista";^{3.2} It pertains to the optic array that a viewer receives while in motion. In other words a viewer's awareness of a series of events.

The act of one object interfering with the array of another object is what we call occlusion. We recognize two types of occlusion. Static occlusion which is also a pictorial depth cue, and kinetic occlusion. Kinetic occlusion is related to actual motion.



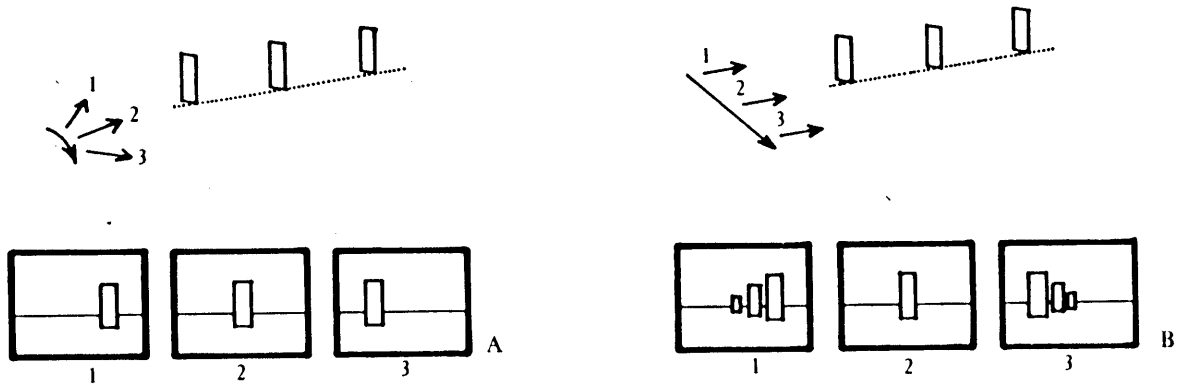
3.3 The depth cues as cases of organizational simplicity. (A) a simple picture using four monocular depth cues: (1) relative size; (2) linear perspective; (3) interposition; and (4) texture density gradient. (B) Compare each cue as a flat pattern in an upright plane (column I) and as the tridimensional arrangement it represents (column II). Which seems simpler in each case, the arrangement in (I) or (II). If organizational simplicity were an innate operating characteristic of the nervous system, what would this figure imply about depth perception?



3.4 St Paul's Cathedral, London. (Elevation in sillohette)
An example of occlusion.

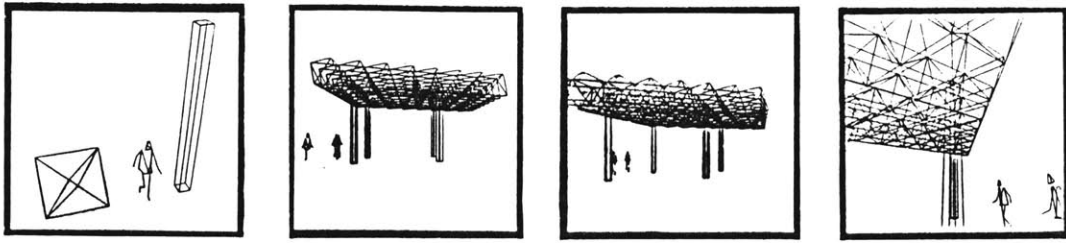
Your vision of an environment is interfered with temporarily by other objects or barriers, thus as you progress through an environment, in turn passing each obstacle, you are presented with a new vista of the scene. When our vision of a scene is interrupted, the next scene we are presented with is examined and superimposed on our previous memory of the environment. With this done, the new vista is accepted and takes the place of the old vista. The link of these vistas create a cognitive map of the environment.

The characteristics of a stimulus and its flow against a viewer moving through space, called the kinetic optic array, have not been studied as extensively as the static array; Therefore there is not a thorough language to measure and quantify the features relating to the transformation of a view in an architectural space or a scene. Some of the more closely related languages that could be developed for use in architecture are in film. Two examples can be given:



3.5 J.Hochberg, Visual Perception in Architecture.
Examples of (A) Pan shot. (B) Tracking shot.

One type of kinetic optic array is achieved when an observer revolves at a stationary point. This camera action in film is called a pan shot. The other kinetic array is when the viewer actually moves from one station point to another called a tracking shot in the film language. Although they could be showing the same scene, the amount of information each offer about the three dimensional depth layout and the number of new vistas they open to view is very different. Pan shots are limiting because they do not enable the viewer to confirm depth. For architecture the movement parallax information offered by a tracking shot can be more useful. It provides the necessary information to distinguish what lies behind an object or any depth information which could be hidden from view.^{3.3}



3.6 Charles Csuri, "Computer Graphics and Art"
 Proceedings of the IEEE .K4

Perceptual theorists have known for a long time that the motion of objects and their relation to other objects is a reliable cue for depth, and a good condition of how to measure an objects distance.

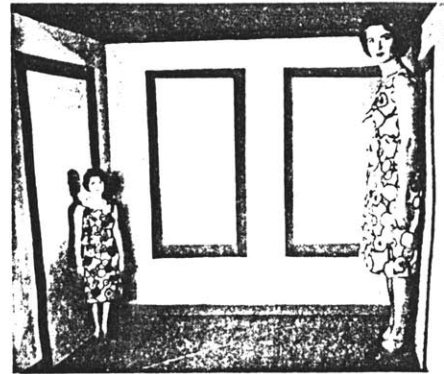
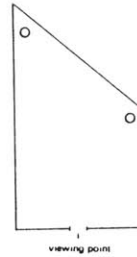
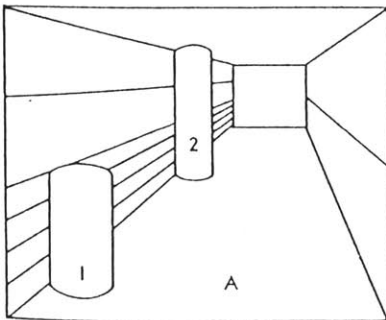
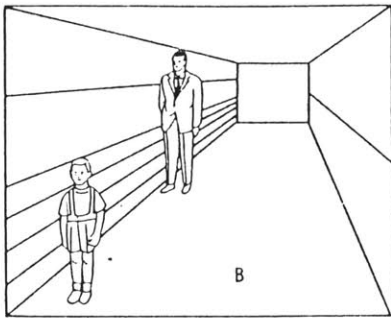
Helmholtz writes; "Suppose, for instance, that a person is standing in a thick woods, where it is impossible for him to distinguish, except vaguely and roughly, in the mass of foliage and branches all around him what belongs to one tree and what to another, or how far apart the seperate trees are, etc. But the moment he begins to move forward, everything disentangles itself, and immediately he gets an apperception of the material contents of the woods and their relations to each other in space, just as if he were looking at a good stereographic view of it."^{3.4}

This does not mean that the movement of the viewer will automatically allow us to discover which 'vista' is flat and which is a real three dimensional space. Were this true we could then ignore the retinal image and the study of perception. The following are examples of the ways optic array can fail to foretell or account for what we perceive.

It is possible for objects to share the same retinal image size, even when they are distinctly different in physical size, and objects of like size can produce varied retinal images. Both types of image depend on the distance from the viewer. Thus we discover that the retinal image size cannot accurately determine perceived size, and should not be used alone but by incorporating with other data, such as, the use of familiar, known sized objects, we can measure more accurately the size and distance of other objects. In architectural representation human figures and other familiar objects are used to convey the size, scale, or the depth of a space, or a scene.

Size constancy is the term psychologists use to explain how the image of an object in our optic array can change dramatically in size, and yet we will still retain our initial impression of the objects form and size. Likewise we see large objects as large and small objects as small even when their proximal stimulus sizes are equal.

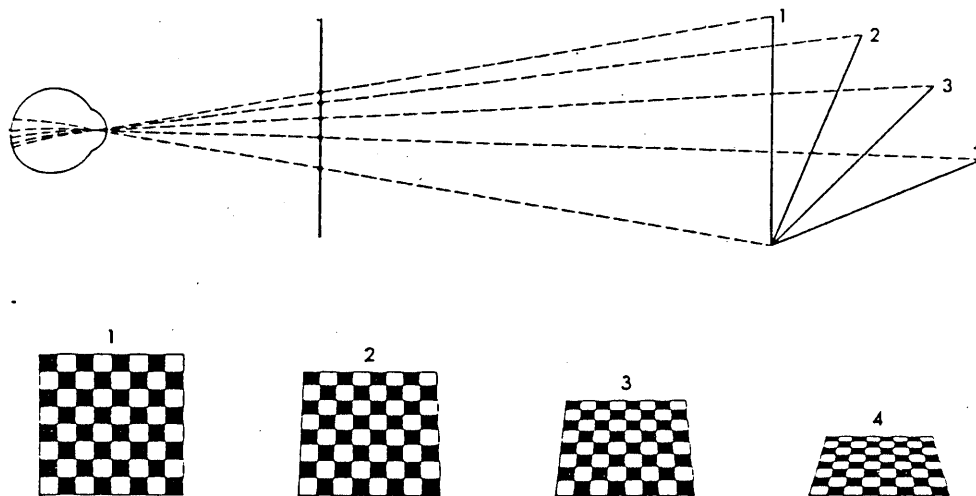
Given that we know the true size of men, boys, and other familiar objects (and recognize them as clues for depth), we might be led to believe that this is why constancy occurs. Yet unfamiliar objects can also be subjected to size constancy; Further more, through the use of false perspective we can create an image of two familiar objects of



3.7 J.Hochberg, Perception. The effect of context on apparent size.

equal size, existing next to each other, but having a well apparent size difference; When in reality the objects are actually some distance apart. In this way we can promote size constancy through deception;^{3.5} and also question the validity of familiar objects as concrete depth cues.

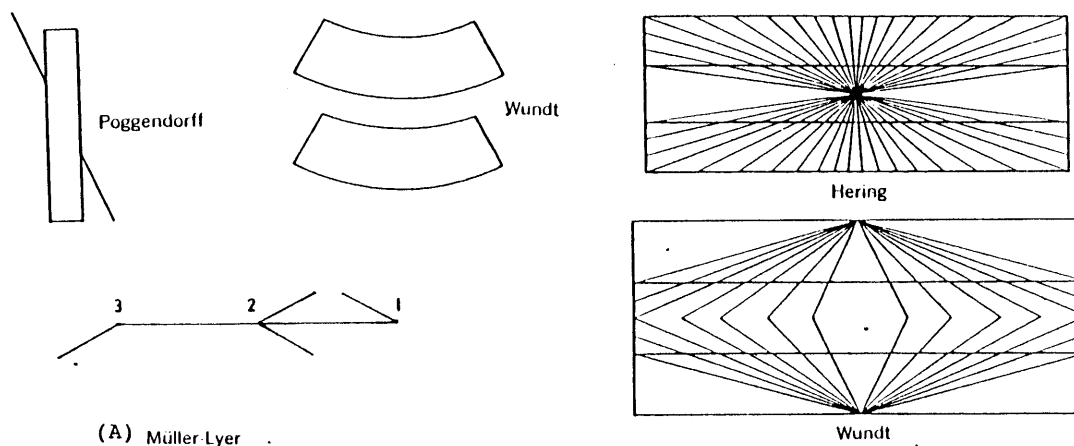
If you could measure the relationships between the sizes and shapes of building surfaces, and contrast them with apparent perceptual changes that occur as you approach the buildings, you would note greater differences in the foreground, while changes in the background could be less detectable; and still these are changes in the image and recognizable as such. We can still acknowledge a shapes actual properties even when we cannot see it from its optimum viewpoint.



3.8 J.J.Gibson, Senses Considered as Perceptual Systems

A pictorial representation of an object or a scene and how closely we can get to the actual perceptual constancy of the real scene is dependent on the effective usage of depth cues; such as linear perspective, texture density gradient, or the use of familiar objects.

In order to have a retinal image that is an exact perception of the actual physical shape of an object, you would (in theory) be restricted to one specific vantage point. With each progressive change in position, the information relayed contains less of the attributes of the original physical shape. Eventhough a shapes retinal image is not absolute, we know that a shape itself is; Without this image rational a simple design would be a formidable task, with design considerations being given to every possible vantage point; Not only could this prove to be impossible structurally but also aesthetically, and economically.



3.9 From E.B.Titchener, *Experimental Psychology*.

PERCEPTUAL ERRORS & ILLUSIONS

3.3

Another example of how an optic array cannot explain what we perceive has to do with perceptual illusions. There are many examples of such optical errors which psychologists have studied.

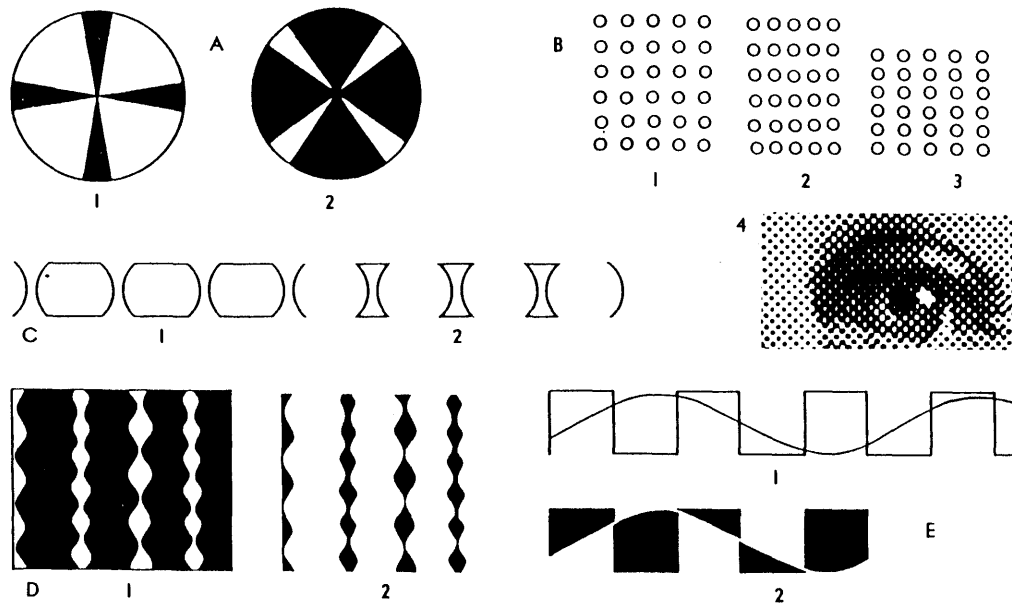
"According to the perspective theory of the Mueller-Lyer Illusion, for example, the converging lines of 1 and 2 in figure 3.9-A have been thought to suggest the depth cue of linear perspective. Therefore it has been reasoned, segment 1-2 appears nearer than segment 2-3; Since 1-2 appears near while subtending the same visual angle, it should appear shorter than 2-3. This would explain the illusion as being due to the unconscious use of a depth cue where there is, in fact, no real depth."^{3.6} As the retinal size of the horizontal section 2 remains constant, should the distance appear to decrease, the size would also appear to decrease. This reasoning would also apply to various other size illusions.

Any shape can be reproduced through use of various elements, and that form can be altered by it's content. The Gestalt school, whose intentions were to re-analyze our perception of the world, has done extensive studies on the subject of figural organization and what is finally perceived. We can address some of these issues which have some significance to the perception of architecture; They argue:

"Determinants of organization, ...are based on the figure-ground demonstration: Perceived figures appear to have a hard surface, with recognizable shapes and definite boundaries. Whereas ground is less surface like, without definite boundary or shape, and appears to extend some indefinite amount behind the contour that belongs to the figure. For a shape to be perceived, it must be a figure: the same outline can be perceived as different, alternative figures, with very different form. The perceptions of objects and buildings, of depth and spaces, of patterns and scenes - all of these rest on shape perception."^{3.7}

Thus several conclusions were set to explain what would be perceived in a figure-ground organization.

- a. AREA: The smaller a closer region the more it tends to be seen as figure. (figure 3.10-A)
- b. PROXIMITY: Objects that are closer together tend to be grouped together. (figure 3.10-B)



3.10 J.Hochberg, Perception. Examples of the Gestalt law of organization.

- c. CLOSEDNESS: Areas with closed contours tend to be seen as figure more than do those with open contours. (figure 3.10-C)
- d. SYMMETRY: The more symmetrical a closed region, the more it tends to be seen as figure. (figure 3.10-D)
- e. GOOD CONTINUATION: The arrangement of figure and ground tends to be seen which will make the fewest changes or interruptions in straight or smoothly curving lines or contours. (figure 3.10-E) ^{3.8}

These laws could be conflicting with one another; their relative strength and which would dominate the other is not yet known; therefore we cannot explain or predict which figural organization would be perceived, unless in their simplest forms.

If we take the position that a viewer's movement relative to the world can provide all the necessary information about the spatial order of surfaces in space, then an observer moving in an urban context, would experience no figure-ground ambiguity and the Gestalt theory of organizational factors would not be applicable. However it has been demonstrated that such movement parallax informations, do have their limit of specificity, and that organizational arrangements can indeed have a significant affect on what is perceived.

Hochberg offers some evidence to clarify the argument:

In comparing an architectural model to an actual architectural setting, not only are the sizes different in relation to the viewer, but the information that the viewer is capable of receiving from each is different. In the case of the model, because the movements of the observer are both larger and faster in relation to the size of the model, motion parallax can provide information concerning the spatial organization of the surfaces. Yet in the actual architectural setting, the relative size of the observer and his movement as compared to his environment are so insignificant that the received motion produced information becomes less perceptable.^{3.9}

The visual field angle through which we perceive relative depth is very narrow. Thus our sensitivity to motion produced information of a scene is limited. When you are studying a detail of a large object, your field of vision may

encompass the whole object but your awareness of that depth information is obscured by your focused attention on the specific detail.

Vision is predominantly peripheral. A first glance of any scene reveals indistinct masses. It is only through eye movement that details can be added to this first impression. In front of us is set the physical world, for the most part permanent and unconfined. Yet the roving eye of the viewer is constantly confronted with a framed visual angle subject to change. This is the window through which he achieves his perceptions and conceptions of the world.^{3.10}

Through peripheral vision once the significant objects of a scene are recognized, the possibility to construct the layout without having to study the whole scene in detail is achieved. But peripheral vision in and of itself cannot guarantee a sequence of events to be perceptually comprehended in an architectural scene. What needs to be taken under consideration is how a viewer perceives in sequence as a result of his movement through space.

"Rhythm is a form of movement ... consisting of time and space, for there can be no movement only through space (without time) or only over time (without space). Only time provides us with an opportunity to substantiate our understanding of rhythm in art."^{3.11}

Successive foveal views of detail take place over an amount

of time within the framework provided by the peripheral context. The time factor in perception is very important. Even small objects need some perceptual storage/memory in order to combine a sequence of glances. In architecture this time factor is amplified because the larger shapes require more time to be experienced, and thus arranged in memory. In film you are offered what is called an establishing shot (or a long shot) which gives the context for the detail in other closeup shots.^{3.12}

"The variety of ways in which architects view their designs is also a unique aspect of their profession. Few other designers rely so heavily on perspective and axonometric projections. The example of "architectural" or "view camera" perspective is particularly unique to the architectural environment. Flexible axonometric systems and the ability to display interior perspective views are also important."^{3.13}

It is often found that when an individual is allowed to explore large scale simulated settings, chiefly in interactive computer graphics displays, they will often seek an overview of the space, this is equal to an establishing shots in film. At present architects rarely utilize such possible interactive facilities.

We know that as the viewer moves the optic array changes, Objects in the field of view exchange places, obstructed objects become visible and so on. For the architect, this creates the problem of providing a set of optic arrays that

are comprehensible, interesting, and aesthetically pleasing.

Up until recently, architects have not have had the tool to enable them to move through space and to examine the relationship of architectural elements to each other and to a particular context. In my opinion the advent of computer graphics (with movement capabilities) can be an ideal tool as an aid for the design of space as well as the communication of it.

"Where the computer has had an enormous impact on design is in the design development phase. It lets us analyze so many issues so rapidly that the architect can immediately see the effect a particular shape or orientation might have on, say the building's structure, energy use, windloading," ^{3.14} and the contextaul environment.

FOOTNOTES

- 3.1 J.J. Gibson, Senses Considered as Perceptual Systems.
 - 3.2 Ibid.
 - 3.3 Julian Hochberg, "Visual Perception in Architecture."
 - 3.4 J.J. Gibson, Senses Considered as Perceptual Systems.
 - 3.5 J.J. Gibson, Constancy and Invariance in Perception.
 - 3.6 Julian Hochberg, Perception. p.55
 - 3.7 Julian Hochberg, "Visual Perception in Architecture."
p.31
 - 3.8 Julian Hochberg, Perception. p.86
 - 3.9 Julian Hochberg, "Visual Perception in Architecture."
p.34
 - 3.10 Ibid.
 - 3.11 N.K. Dokuchaev, "Methodical Notes on the Course
Foundation of Architecture." Moscow: Gozzidate 1927
p.89
 - 3.12 Julian Hochberg, "Visual Perception in Architecture."
p.35
 - 3.13 D.F.Stoker, N.H.Wengarten."CAD vs. CAD" Architectural
Record Dec. 1983 p.21
 - 3.14 Ibid.
-

"It is this ability to simulate motion which is vital, for at the essence of understanding of space is our movement within it."

Tom Porter

VISUALIZATION TECHNIQUES WITH COMPUTERS

When we consider the available design media today, and compare the advantages of models to those of drawings, we find both to be servicable; For instance, models combine spatial information with a three dimensional form that is generally readily understood by the public. However due to their inability to be adapted to changes with ease, models are not used in the preliminary stages of design, but rather they are used to show the final product. " Models serve most often as an explanatory tool than an exploratory device."^{4.1} So the flexibility of drawings, their reproducibility and ease with which you can bring them up to date, makes them an invaluable presentation method and accounts for their prevalence. Computer graphics with it's potential for working in three dimensions can bridge the gap between these two methods.

Computers offer the most comprehensive and flexible systems Of all dynamic image making media at man's disposal, today. All man-made images are divided into two groups, moving and static. There are also two ways to generate them; Through recording, or by construction. As an example, photography, records static images, while cinematography records moving images. For constructing an image, we rely on manual

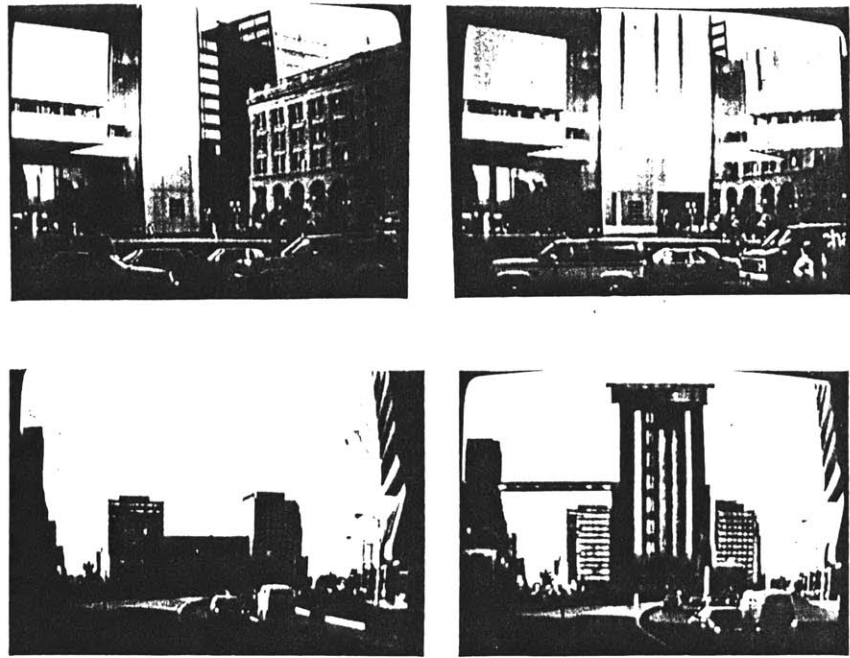


4.1 Marcel Duchamp, Nude descending a staircase. 1912

rendering techniques like drafting and painting. Unfortunately these traditional methods provide us with only static images.

Man's attempts to record movement throughout history have included cave paintings depicting bison with many legs; Echo lines surrounding characters in cartoon strips or Marcel Duchamps 'nude descending a staircase' as a time exposure.^{4.2}

To fulfill the need for fabricating moving images, computers seem to be the answer. They offer the most convenient method of constructing dynamic images; in fact because the computer itself can have a dynamic environment, the user can turn a still image into a moving one. For the computer, movement, as another dimension, is no more difficult to calculate than the other spatial dimensions.



4.2 Tyler Peppel, 1984 Live Action Video with Digital Imaging

One of the most realistic simulations is produced by combining a computer generated model with advanced film and video technology. This can provide the closest sensation possible to traveling through space.

As an example of computer graphics imaging intergrated with other media, live action video was combined with a computer generated image. The architectural usage of such a technique is: "Digitally created structures may be viewed in any number of environments by simply playing a variety of analog footage in combination with the graphics... Redesigning the urban environment is only one limited application of the ability to dynamically redesign the visual content of a video tape sequence within the context of movement and time."^{4.3}

In architecture today, computers, specifically computer graphics are primarily used for drafting, cataloging and handling information rather than as a design tool. The capabilities of today's computer, allows you to have a dynamic imaging tool to express dynamic ideas.

It is customary for the designer to translate his mental three dimensional image to a two dimensional drawing then later back into a three dimensional model. Computer graphics can eliminate this costly and intermediary step; by taking the designers concept direct and recreating the same three dimensional image.^{4.4}

"The computer technology has moved so rapidly that it has outpaced our ability to apply it immediately."^{4.5}

In the past, in redevelopment of urban areas, especially low income projects, it was common practice to design a series of identical buildings that by their simplicity would defer the possible high cost of building and design. Unfortunately this practice makes for a rather sterile living environment.

"Design is a discipline of function, logistics, and economics moulded by aesthetics. The first three parts of this formula can be safely turned over to the machine, thereby freeing the designer for his most meaningful contribution, that of aesthetic."^{4.6} Lawrence Lerner

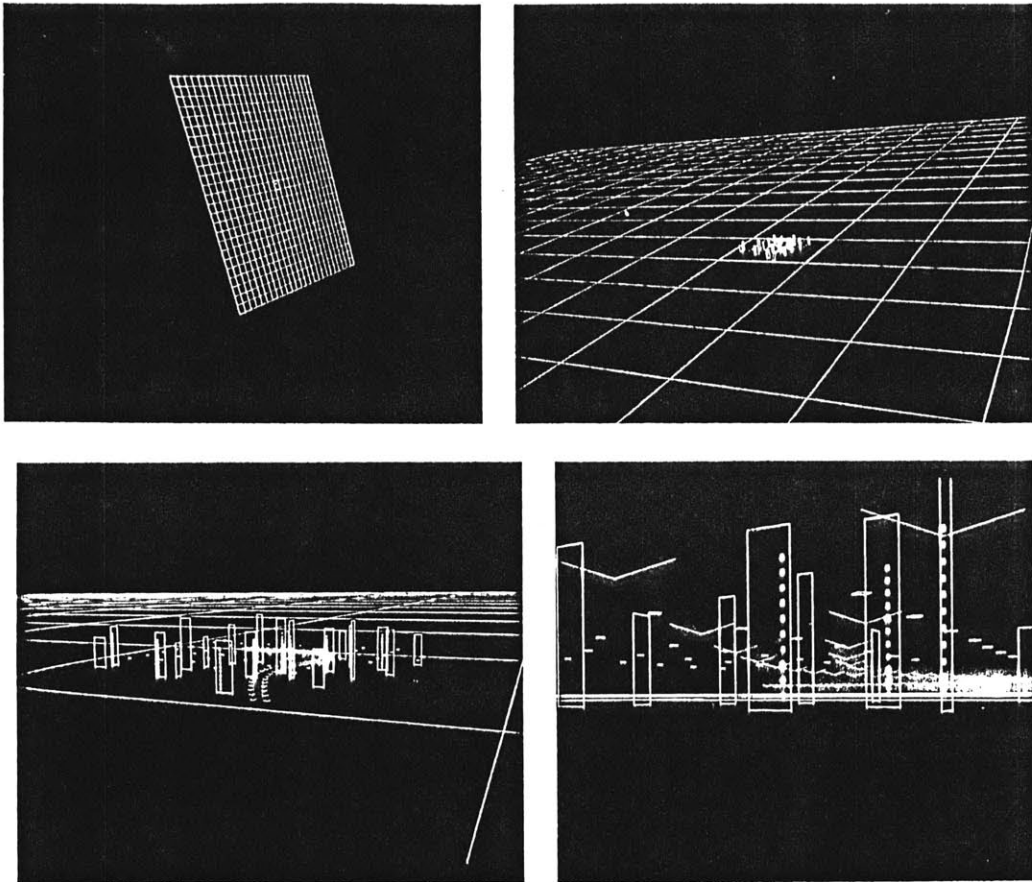
With the advent of the computer age, most importantly computer graphics, design compromises can be avoided. The computer can store all building codes, construction and graphic symbols; With the computer keeping track of all system information, such as structural, mechanical and even cost factors, the designer can devote his energies to composing an environment that not only meets the project requirements, but also considers the final outcome from a humanistic approach.

Once construction information is loaded as a data base, views can be created from any angle in any direction.

The computer can simulate an observers walk through the entire space allowing the experience to register on the perceptual senses as it would happen in reality; "stressing the whole urban experience as opposed to the momentary 'jewel'."4.7

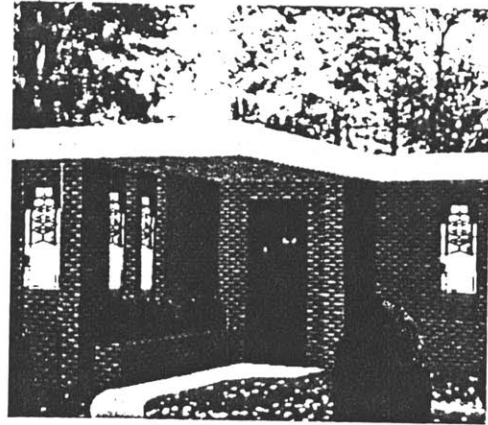
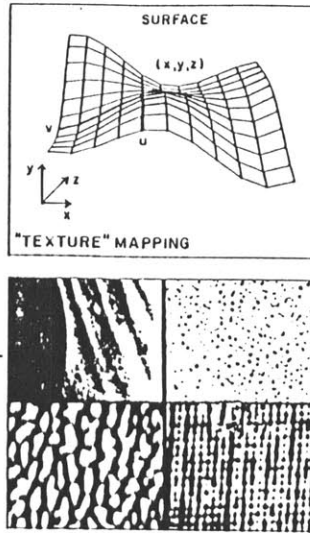
"The only convenient way of constructing a dynamic image is to work with a 'dynamic environment' that will transform the still image into a moving one."4.8

Because architects have no testing environment with which to explore and predict the effects of an architectural space beforehand, has provided the impetus for much research, for in our ever complex and changing environment, designers are confronted with deadlines to problems of increasing complexities, some problems that as yet have no past reference to draw solutions from.



4.3 "City Scape". Moving Picture Company, England.

The benefits of a computer generated model are numerous. The designer is allowed the freedom to rapidly reshape concepts in space three dimensionally, bring forth an assortment of forms stored in the memory, and assemble them on a given site. A free form contour can be combined with a given object and then transformed into a perspective allowing the designer to zoom in and walk around the resultant space. Objects that are illuminated by the sun will cast accurate shadows and reflect light or receive shade from nearby objects. With the aid of more advanced programming, such as a program by professor Greenberg of Cornell University, called Stretch, a computer can generate theoretical three



4.4 "texture" Mapping. Programs of Computer Graphics, Cornell University.

dimensional concepts of buildings in color. These can then be overlayed on photographs of existing sites and with a simulation of real time movement an architect can explore visually the implications of his concepts of space.^{4.9}

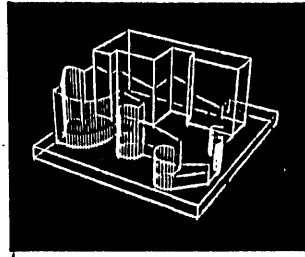
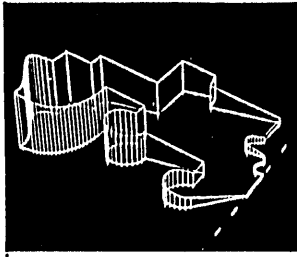
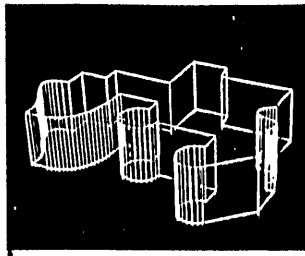
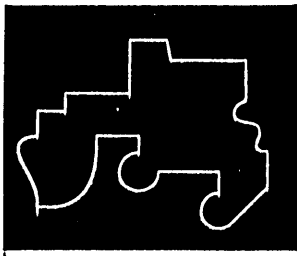
The utilization of computers for accurate rendering was begun by Dr. James Blinn. "Starting with a wire frame drawing composed of lines , he added solid blocks - creating surfaces - and then overlaid these surfaces with textures to give them the appearance of reality." In this way he made the techniques known as surface modelling effective for the realistic rendering of three dimensional objects. Today, once the programs are written, it is relatively easy for even a novice to create any object using the same techniques.^{4.10}

For the most part, present day use of graphic displays utilizing real-time capability are limited to flight simulations in military training and simulations of space vehicles passing planetary bodies.

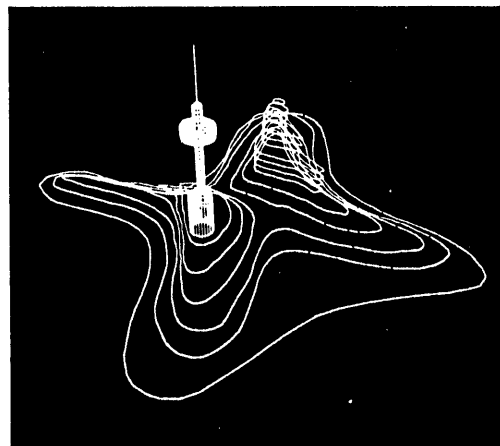
Though we have progressed rapidly in our ability to generate realistic images, our methods of inputting geometric information have not kept up the pace. These difficulties in communicating the spatial information of objects combined with mathematically complex input methods have often discouraged the use of computer aided design facilities. In order for CAD systems to be truly effective they must be user friendly by allowing the user to define, manipulate and edit the object and also rapidly display it for visual confirmation. Some of the devices that empower the user with the ability to perform complex functions with ease are; the light pen the digitizing tablet and the joystick. There are a number of methods of graphical inputting that are becoming more widely accepted and taking the place of the standard method of typing numerical sequences.

"One very popular method is known as "lofting", where a set of serial cross-sections of an object are interactively defined. This is like tracing the contours from a topographic map. Each figure has a precise elevation. (figure x) The computer can automatically combine these two dimensions to create three dimensional shapes." 4.11

"A second approach can be thought of as an extrusion method.(figure z) A line can be generated from a point, a solid from a plane. In each case, the direction of the extension can be controlled and has a unique relationship to the original two dimensional definition. This "sweep representation method" is very appropriate for architectural design." 4.12



(A)



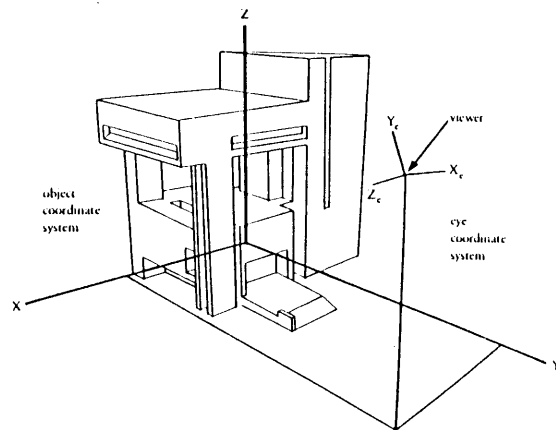
(B)

4.5 A. Extrusion. B. Lofting.

Programs of Computer Graphics, Cornell University.

Essentially, a computer graphic system is made up of a main processing unit, a display processor and an interface. Obviously the size of your "core store" (memory bank) will determine the amount of detail that you can specify; but it is the peripheral equipment which is most important to the designer. For it delegates the ease with which you can communicate with the computer and hereby generate the image.

Having entered the information for a three dimensional model, you would like to transfer it onto the screen. The central processing unit has stored all the coordinates of the model in it's memory. You have to call up a specific point of view for the image because the computer needs to know the relationship of the observer to the object. Given these new coordinates the computer calculates a number of views to represent the desired image. In a sense, the computer photographs the image from different points of view in it's memory.

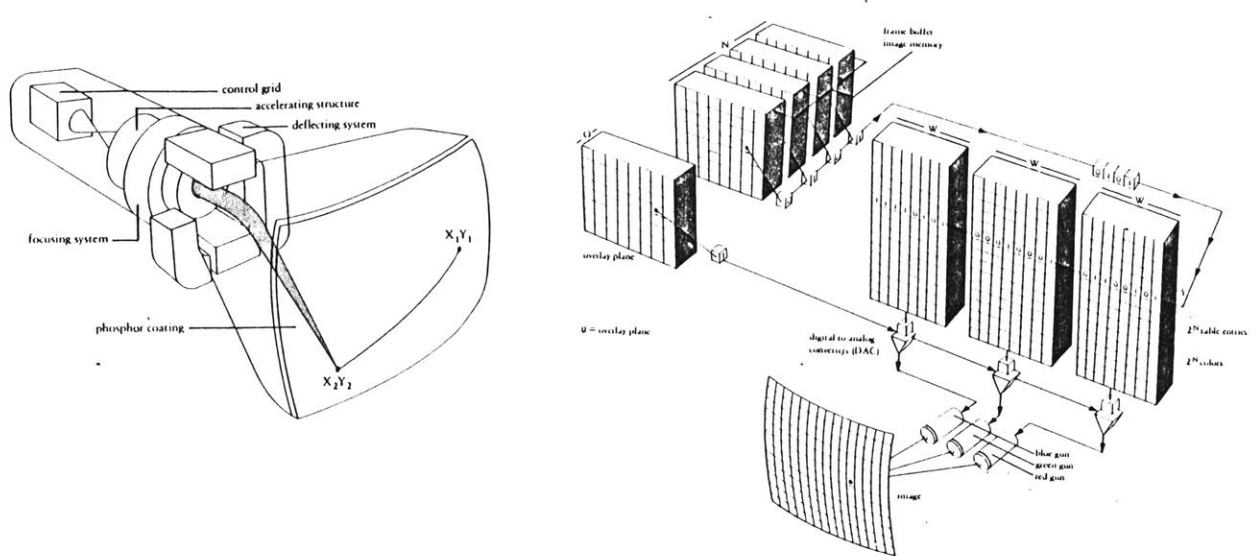


4.6 Object and Eye Coordinate Systems.
D. Greenberg The Computer Image.

One of the greatest advantages of computer graphics is the immediate visual feedback. Yet the journey to the screen is not so simple. It involves the transformation of the three dimensional description into a two dimensional perspective. This determines the intersections of View Rays - (A line connecting a point in the environment with the eye of the viewer) - emanating from the viewers eyes with an imaginary picture plane.

"To mathematically calculate the position of a point on the display screen that corresponds to a point on some object, the standard procedure is to first transform the point from the "object coordinate system" to the "eye coordinate system", where the origin is fixed at the viewpoint and the Z_e axis is pointed in the direction of view. The coordinate system is fixed to the observer's eye: it moves and rotates as the eye moves and the head rotates.(figure 4.6) A viewing transformation matrix is used to enact this transformation. Note that the eye coordinate system is a lefthanded cartesian coordinate system, with the X_e axis to the right and Y_e upward to align with the X_s and Y_s axis of the display.

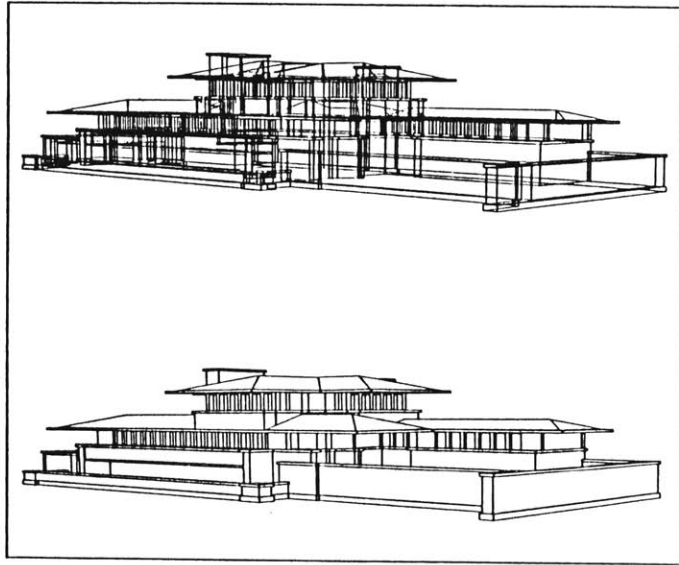
A perspective display can be generated simply by projecting each point of an object onto the picture plane. The coordinates (X_s , Y_s) of the projected image are easily computed from similar triangles but require dividing by the depth (Z_e) coordinate value." 4.13



4.7 (A) Vector and (B) Raster Displays.
Donald Greenberg The Computer Image.

Surface Detection

After the computer has begun the process of transforming the three dimensional model into a two dimensional perspective, it must make decisions regarding all visible lines and surfaces. Surfaces that are hidden or portions thereof that are occluded must not be shown. This is not an easy task for the computer because it does not know what parts of the environment are not visible. We have no trouble making these distinctions in real life because we cannot see through opaque objects. In a Vector display the solution is to determine the end points of all line segments, however for Raster screens it is necessary to compute the visibility at each point (Pixel) of the image plane. (Pixel, short for picture element, is the shortest unit available for display on a raster screen, representing a single graphics point.) Each point in a plane must be compared to every other point



4.10 Hidden Line Removal.

Programs of Computer Graphics, Cornell University.

to determine which is closest to the observer. The more complex an environment the greater the number of points to be measured and so the greater the amount of time to compute. An approach to the problem is to categorize solutions two ways. Object space solutions perform the calculations in three dimensions and at the mathematical precision of the computer. Image space methods retain depth information but sort by lateral position of the picture and only to the resolution of the display device.

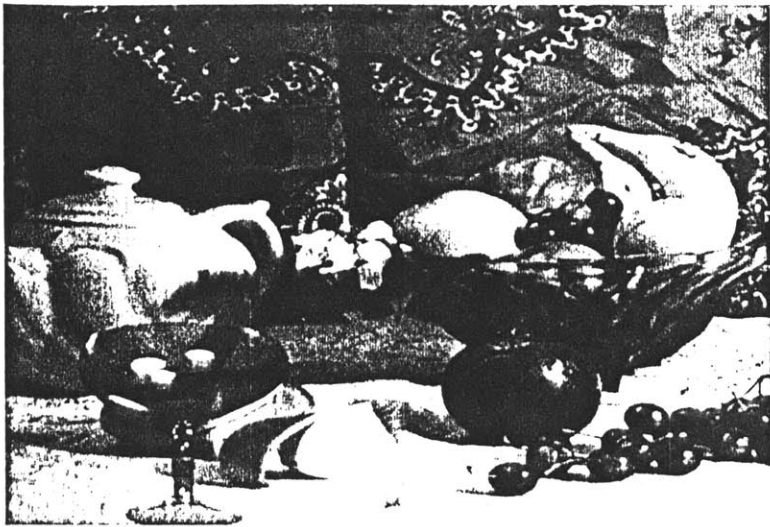
The next step for the computer is to sort the front facing points from the back facing points. There are three prevalent image space methods, Windowing, Scanline, and Depth Buffer. Window methods repeatedly divide the image into smaller windows until either the visible surface is easy

enough to discern or the window is as small as the desired resolution of the picture.

Scanline methods sort only those planes in an object space that are intersected by a plane containing the given Scanline. A Raster screen image is generated by sweeping horizontally across alternate scan lines from top to bottom. Specialized computer hardware can perform these functions fast enough to simulate motion.

The Depth Buffer approach is by far the simplest. The idea is to calculate the intensity of each Pixel. The intensity will be based on the color of the point closest to the observer. Depth calculation is simplified because the perspective is an orthographic projection.

Two of the disadvantages of these image space methods are that information is lost because of the sampling nature of these methods, resulting in jagged edges or lost points. Second, environmental description is ignored, thereby eliminating shadow and texturing. Object space methods avoid these problems, maintaining three dimensional environment data and precisely computing the information.



4.8 Program of Computer Graphics, Cornell University.
Model Shading, with Transparency Simulation.

Shading Models

Having distinguished all visible surfaces, we must next find the correct intensities for each Pixel. This is dependent on an accurate model of how objects reflect light. It must include color and spatial distribution of the reflected light. Most shading methods presume that the intensity of reflected light is related to the composition of the source, direction, and the orientation and the textural properties of the surface.

The action of light striking a medium results in three possible events. The light will be transmitted, as with transparent objects. The light will be absorbed by the object and converted into heat. The light will be reflected.

In shading models reflected light is made up of three elements, ambient, diffuse, and specular. The ambient light element is attached to incident light from the environment

and so reflected equally in all directions. Diffuse and specular elements are related to specific sources. Because reflected light is dispersed equally in all directions, we can also say that the viewers position in relation to the surface does not affect the intensity. Ambient light accounts for some portion of reflected light and this is why objects that do not receive direct lighting are rarely rendered completely black.

Specularly reflected light is bounced off an object without entering it, as in the case of a mirror. Since the angle of reflection equals the angle of incidence, the amount of this type of light that the observer sees is dependent on the surface orientation with respect to his position.

Color

Another model calculates the color shift of light. This can be expensive computationally but has proven to give the most accurate renditions.

A Ray Tracing method extends a "tree of rays" from the viewer. When the rays arrive at their first surface their dispersal is calculated and they continue on. This method can enable the viewer to model transparent objects.

There are two catagories for specifying types of color. One is recreating the color of an existing environment. The other is psuedo-color, where the color is used as an abstraction.

In conclusion, we find there are five major steps required to create a continuous tone computer image, (specific to raster screens):

1. A mathematical description of the image must be fed into the computer.
 2. The three dimensional image must be transformed into a two dimensional perspective.
 3. A determination of all visible lines and surfaces must be made. This is known as visible line or surface algorithm.
 4. An illumination model must determine the shade or color of each surface.
 5. The appropriate red, blue and green intensities must be selected to represent the color specified by the illumination model.
- 4.14

INTERACTIVE DESIGN SYSTEMS

4.2

For a computer to be able to simulate effectively it relies on two things.

1. It's own ability to process and read complex information, such as points, lines, curves, shades, color and specified three dimensions from the designer.
2. The degree of it's interactive capabilities, i.e. whether given an uninterrupted flow of information it can continuously update the existing data.

We distinguish an interactive computer by saying it is "event driven". The computer waits after the completion of

each command for the operators next move. If the operator enters new data, and that information would effect the defined object on all levels, then that information needs to be given to the host computer. Having done this all subsequent views will reflect that change. Alternatively if the operator merely wants to zoom in to one particular aspect of the object this kind of move can easily be accomplished by the display processor provided that the image has been loaded into it. When we say that a graphics system is "event driven", we mean that it relies on input from the designer. When processing an image it waits for each command. Given the large amount of processing capability needed for a graphics system, one small change in a design could tie up a companies mainframe to the exclusion of all other work. This is when the advanced technolgy of the new display processors could easily accomplish the task leaving the mainframe free to attend to other projects.

The evolution of computers thus far has seen the increased ability for the display processor to handle more of the menial jobs previously designated to the mainframe. "Distributing the intelligence", is the term coined for this development. Display processors have now been endowed with enough intelligence and calculation abilities to make them CPUs in their own right.

If you examined the process of drawing a circle you could see how the computer works. An interactive computer responds to

an operators commands by noting "your move, my move". For example the operator picks "circle" from the menu. The computer brings up it's drawing routines. The operator locates a dot for the center of the circle, at this point the computer waits because it "knows" that you need 2 commands to draw a circle, one for the center, one for the circumference. The operator locates a second dot. The computer switches to it's circle drawing routine and generates a circle. The interactive process continues because circle drawing is an easy task and it takes almost no time to appear on the screen and the computer "knows" what it has drawn. From this stage the operator can work with the computer on a higher level. The computer can treat the circle as a whole, and so it can be manipulated on the screen. All this is made possible by the expanded power and memory capacity of the display processer.

We can base our support of computer graphics as the optimum method of communication on the following reasons .

1. The many possible viewing points and distances available.
2. In certain cases existing mathematical descriptions of subjects and mathematical analysis of movements may be used.
3. That data are expressed as finite numbers prevents the build up of dimensional errors.
4. The computers capacity for storage and processing allows drawings to be detailed in depth.

Comparatively inexpensive processing and greater accessibility has made dynamic computer imaging more practical and has opened the field to include the technologically advanced architectural firms not just university reseachers or the military.

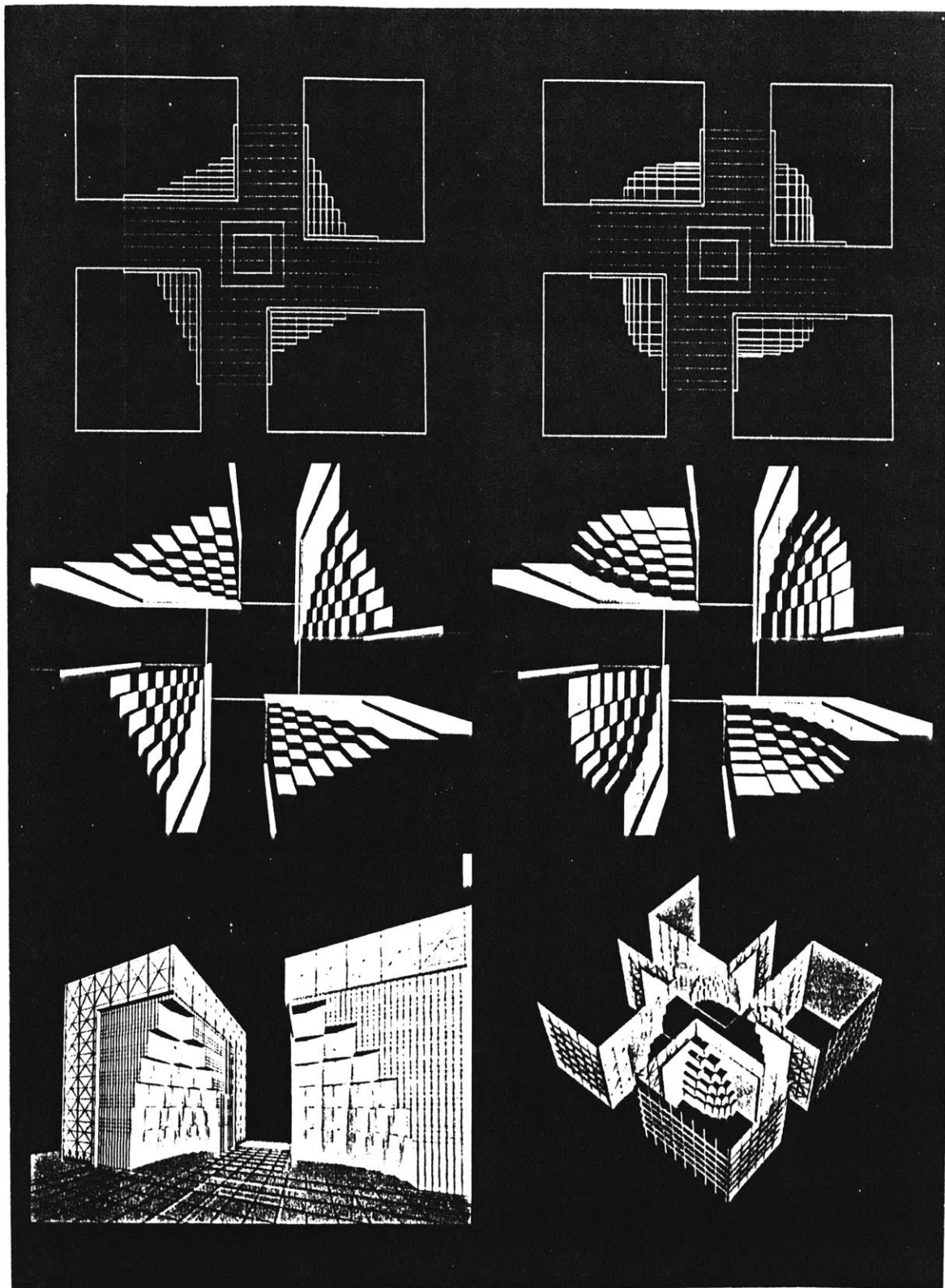
With the introduction of the relatively inexpensive micro-processor, manufacturers have developed special machines to display views dynamically. One company carrying such product is the Evans & Sutherland Corporation. Their device is a high resolution color monitor powered by a computer supplemented with additional circuitry that can produce representations of three dimensional objects. This machine has the capability of calculating and displaying shaded perspectives 30 times a second. At this speed, it is conceivable to show an object in motion. Conventional computers cannot perform this function, at best they take several seconds to calculate the movements for a single view.

At present the cost of such special machines still places them out of the reach of most architectural firms, but as we progress further into the field the future may hold an affordably priced machine for larger firms.

Among architectural firms, skidmore, owings and merril has had extensive involvement in computers, specifically in the development of CAD. "Their system ties together all facets of design, from the initial sketching, design development, and presentation through engineering analyses and working drawings, to project management. Much of their research focuses on the initial design phase, for example the effects of specific materials.

In an interview in Progressive Architecture, Douglas Stoker, director of computer services, discusses the specifics of architectural design and how computers can serve these needs. The three major components of a CAD system for architecture are: Its graphics capabilities, its data base structure and its application programs. As for the graphics capabilities they say that "only in architecture is the visual presentation of a design problems so closely linked to its solution. Architectural solutions have a greater number of elements than most other design solutions. They require a vast number of colors to render shapes and shadows and to represent solid and void. Also they rely heavily on perspective and axonometric projections." 4.15

If architecture is the sole design media that ultimately links the visual presentation of a design with it's solution. Then how we interact with our drawings determines the rate and result of our progress. This is in evidence in many areas.



4.9 Skidmore Owen & Merrill
Two Detail Design Proposals.

Obviously the number of components in an architectural scheme is great. Backgrounds alone can require thousands of lines. An accurate facade could incorporate over 100,000 elements, their size ranging from hundreds of feet to fractions of an inch. The scale of an environments actual size and it's presentation size is 100 to 1000 times larger than other design professions. There are very few systems able to display these ranges and amounts of data, that heretofore architects orchestrated on vellum.

"If there is any remaining doubt about the amount of processing needed in graphics application, Merely consider the simple arithmetic of it. Suppose the picture is a modest raster image of 1000 x 1000 picture elements. Each one of these Pixels might be switched to 10 different levels of intensity, that is: 10 degrees of brightness, and each one might assume any one of 10 different combinations of red, blue and green, the three primary additive colors. If you wanted to see an image in which most of the Pixels were used, and which could move in real time, you would have to use a computer that could consistently perform at least 100 million calculations every 1/30th of a second." 4.16

With financial support of the film and television industries, researchers have spent much time on a "quest for realism" in computer graphics. The results to date indicate that while realistic images are possible, it is not economically feasible to generate them in real-time, yet; " 'Realistic' images consume very large amounts of CPU power, sometimes requiring several seconds on supercomputers such as Cray (or even several hours on Vax-11/780) for each frame." 4.17

"The articulation of elements computed in the three dimensions encourages a different way of thinking about design. The provision of this new, more realistic mental

perspective equates the importance of the invention of computer aided design with Brunelleschi's invention of linear perspective. For it has not only freed the designer from the preconceptions associated with static drawing but opened new windows on his spatial thinking and brought him inside a concept that was, hitherto, inside his head."

C.H. Eastman

FOOTNOTES

- 4.1 Tom Porter, How Architects Visualize. p.84
 - 4.2 L. Moholy-Nagy, Vision in Motion. p.249
 - 4.3 Tyler Peppel, Digital/Analog Video. p.59
 - 4.4 Nicholas Negroponte, The Computer Simulation of Perception During Motion in the Urban Environment. p.124
 - 4.5 Donald Greenberg, The Computer Image. p. 30
 - 4.6 Tom Porter, How Architects Visualize. p. 104
 - 4.7 N. Negroponte, Computer Simulation of Perception During Motion in the Urban Environment. p.152
 - 4.8 John Lewell, Computer Graphics. p.19
 - 4.9 Tom Porter, How Architects Visualize. p. 100
 - 4.10 John Lewell, Computer Graphics. p.17
 - 4.11 D. Greenberg, The Computer Image. p.13
 - 4.12 Ibid. p.14
 - 4.13 Ibid. p.16
 - 4.14 Ibid. p.21
 - 4.15 S. Doubilet, "The Big Picture" S.O.M. Progressive Architecture. 5:84 p.84
 - 4.16 John Lewell, Computer Graphics. p.45
 - 4.17 R.V. Hubbard, "3D Real Time Display & Raster Representation. p.26
-

"Happening attracts us more spontaneously than things do, and the prime characteristics of a happening is motion."

R. Arnhiem.

CONCLUSION

One of the greatest problems in architectural design today, is understanding the three dimensionality of a project before it has been built. Even though architects are trained to think spatially, their primary means of communication are still through two dimensional representations; plans and elevations. Computer graphics techniques can allow designs to be evaluated thoroughly at the preliminary stage, and the construction of elaborate and costly scale models can be replaced with fully textured and shaded images on computer screens, images that can be manipulated on screen, from any possible viewing angle. What the future holds is the ability to walk about the project before the construction documents are even begun.

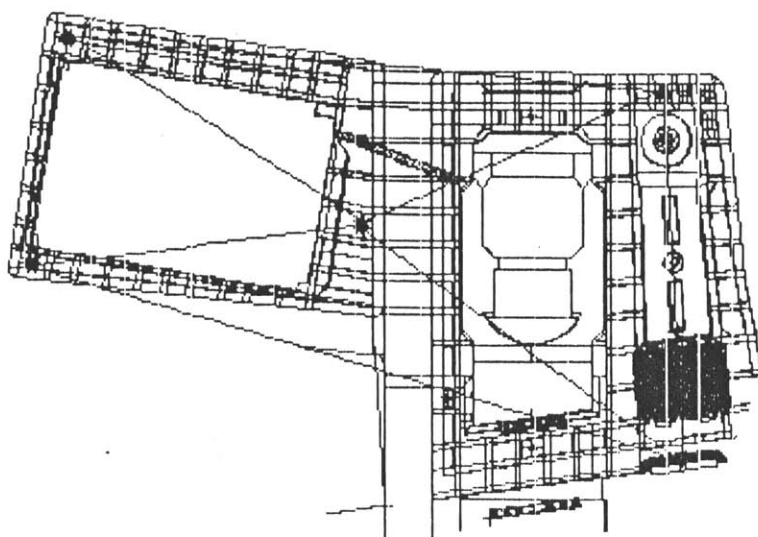
Only time can tell us what impact a system with real-time movement capabilities would have on design. At this point even the potential worth of these systems has not been measured. In the days to come, designers will become more aware of the laws of perceptual experience and the need for a truly effective method of communication, capable of relaying spatial information to another level of understanding, via movement. A computer with dynamic visualization capabilities can support the conceptual ideas of the designer while upholding the integrity of the actual project. Computers will be the ultimate translators of man's concepts of space.

APPENDIX

Performing Arts Center	74
3-D Computer Visualization	77
Computer Wall Painting	79

From:

Ernest Burden, *Design Simulation*.
Wiley Interscience Publication: New York, 1985.



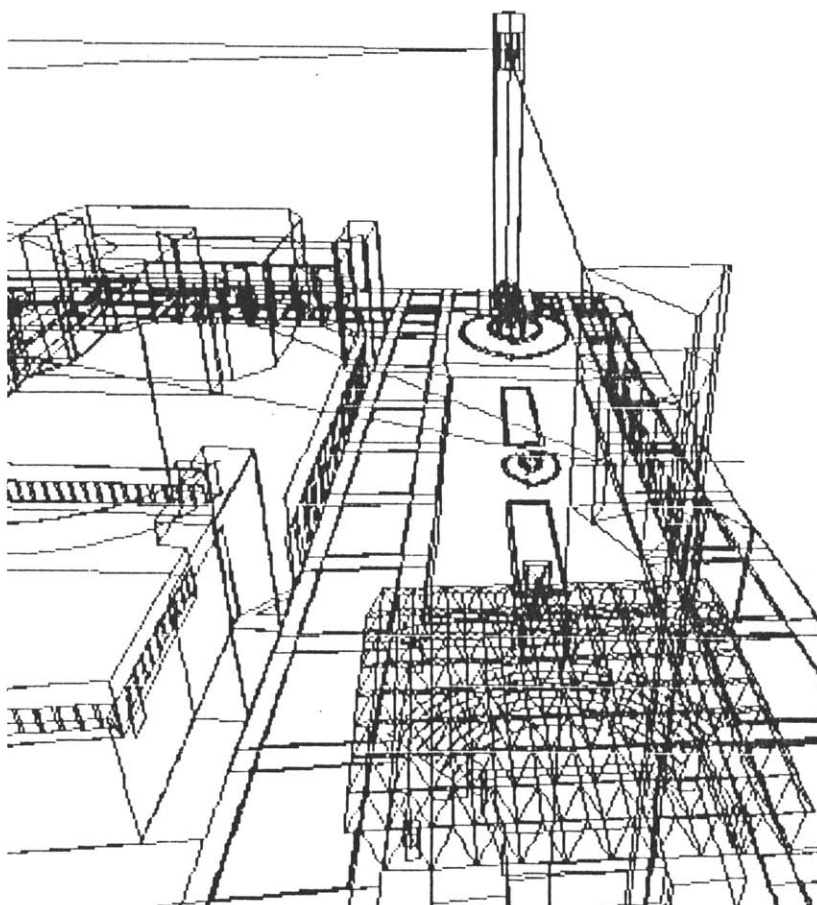
Performing Arts Center

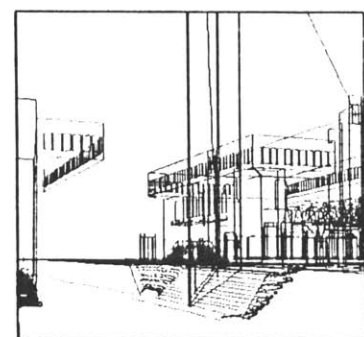
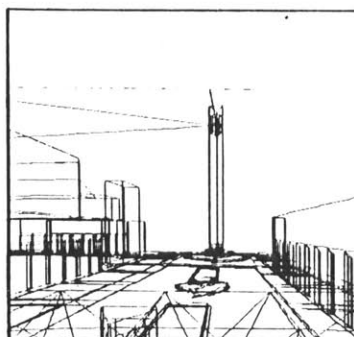
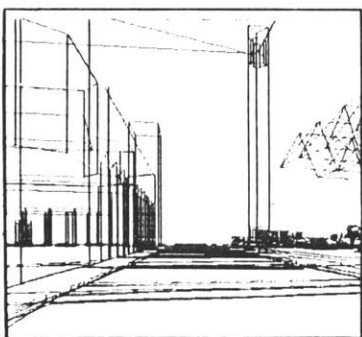
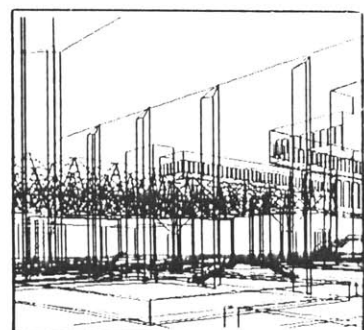
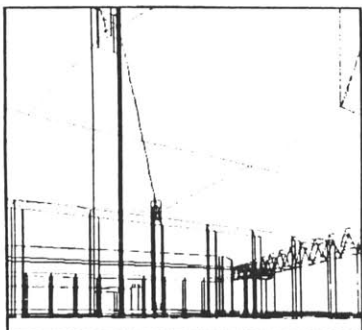
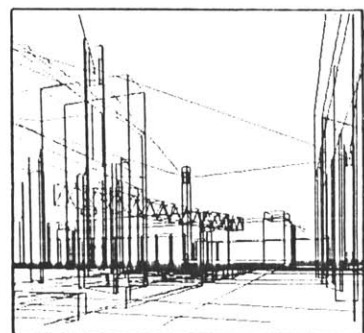
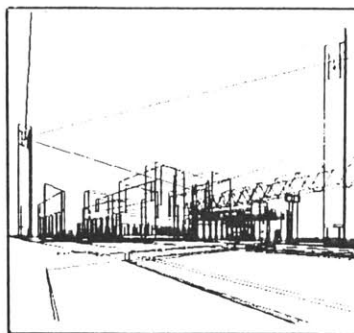
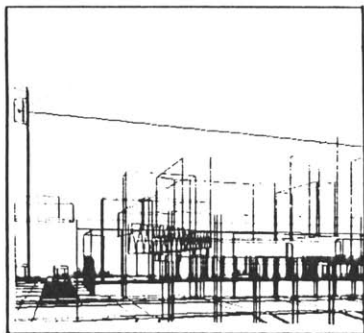
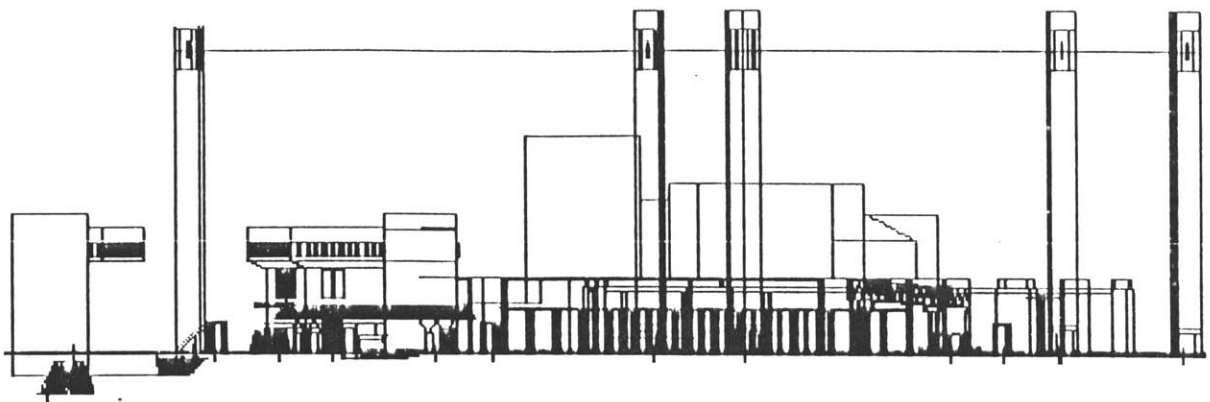
This project was entered in the Environmental Arts Competition whose program was to integrate the variety of structures of the Milwaukee Performing Arts Center. The architects used computers to develop their design.

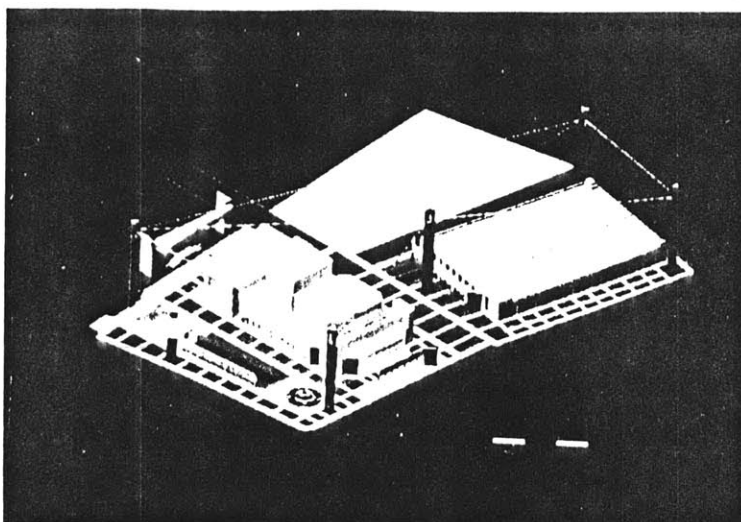
They used the computer graphics lab of a local technical college to enter the existing design conditions into the computer. These comprised the original building and site arrangements as the architects envisioned them, including the main structure of the center, a horse chestnut grove, a water fountain, the parking structure and overpass, and an outdoor pavilion.

First, the coordinates of the existing site and buildings were entered into the computer and a three-dimensional line model was created. Next, proposed design elements were added, viewed from various vantage points, and evaluated; the heights of the laser towers were adjusted and refined, for example, still in line drawing form.

The scheme they developed was inspired in part by Edmund Bacon's *Design of Cities*, in which he examines the use of minarets around a mosque as a device for defining space in Islamic architecture—establishing “a transparent cube of space infused with the spirit of the mosque.” For the Arts Center, the architects proposed “minarets” (based in form on the column detail of the original building) that would transmit laser beams into the sky, enclosing the site in a staccato-colored ring and creating a holographic effect that would broadcast events at the Center to the entire city. Lighting effects were redoubled in reflective glass entrance arches and in reflecting pools encircling the site, defining the property, tying the site to the Milwaukee River, and reinforcing the formal Islamic theme.







Performing Arts Center

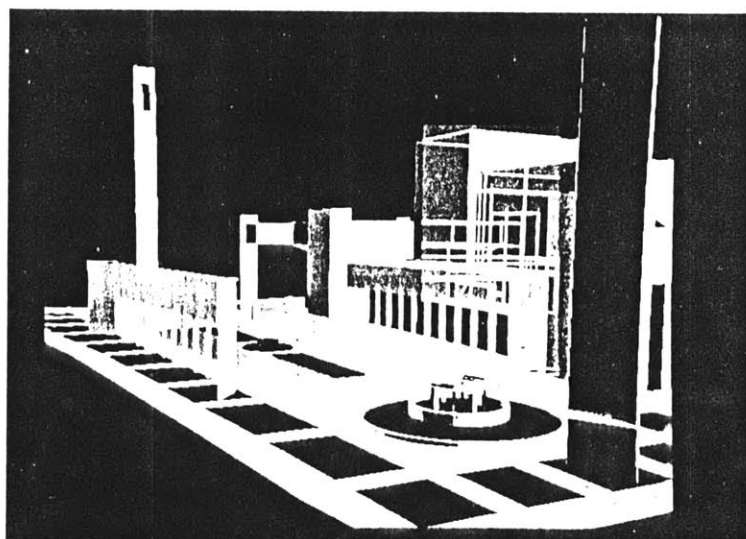
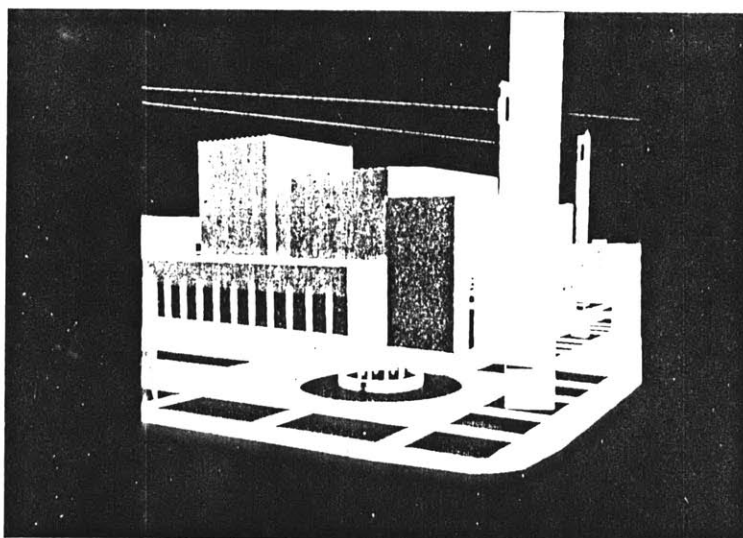
Having developed their design in a three-dimensional line drawing form, they used the data in two ways: to create computer models with solid surfaces, shaded at various sun angles; and to derive dimensioned drawings. Material specifications were added in note form, and parts were refined and reinserted in the overall design.

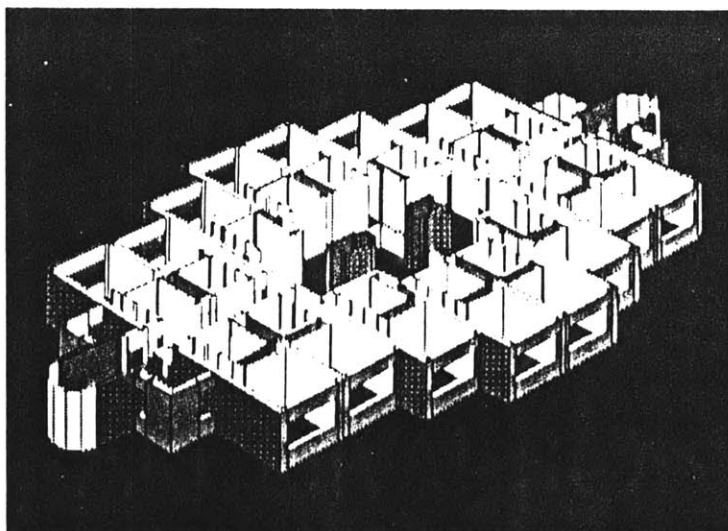
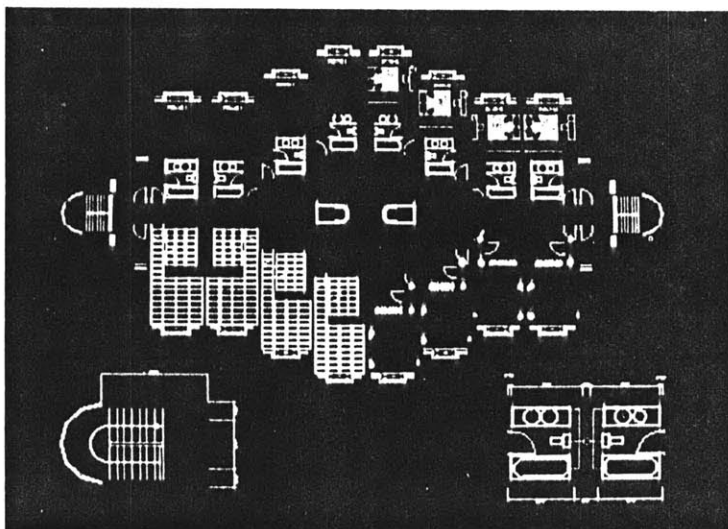
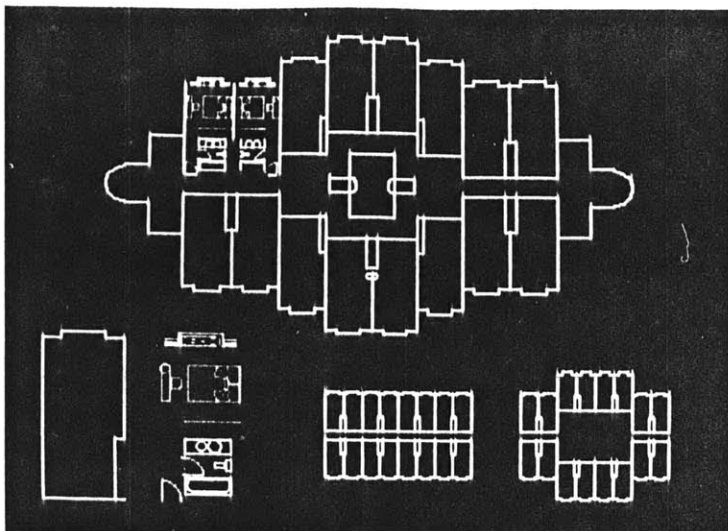
Reproduction drawings of the PAC grounds were obtained from the City of Milwaukee to provide the accuracy and back-up material needed. A three-dimensional model was established of all existing architectural features. From these models, the architects were able to fully visualize the existing massing and site features. Various schemes were developed in sketch form which were inserted into the database. Evaluating the massing, scale, size, and texture helped to solidify the development of the design. The computer allowed them to clearly evaluate the heights of the laser towers by adjusting them many times until they were finally approved by the design team.

Time was also a major factor in using the computer. For example, the space-frame roof truss on the Peck Pavilion was created in less than six minutes. The architects were then able to look at the space frame from various angles in perspective, from an aerial to a ground view, without reconstructing the initial input.

These concepts were manipulated and enhanced with various colors until they felt comfortable with the design. A variety of perspective images was stored in memory.

Multiple perspectives were reproduced on paper via the plotter. Surfaces were shaded at various sun angles using the solid modeling mode. This was then captured on film from the monitors and mounted on the competition's required boards.

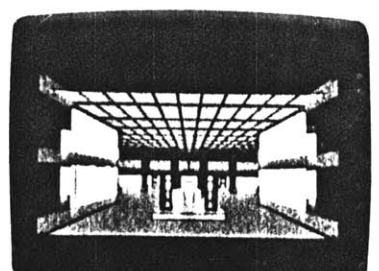
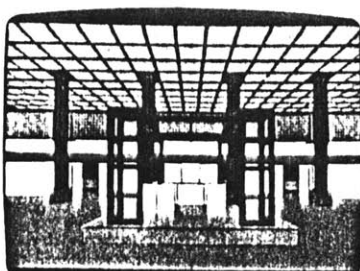
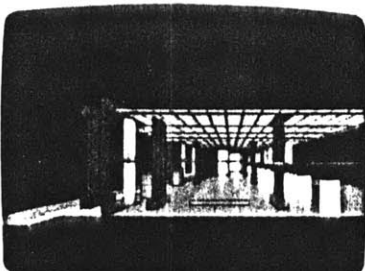
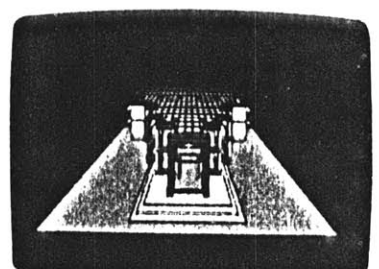
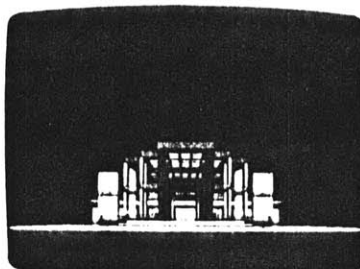
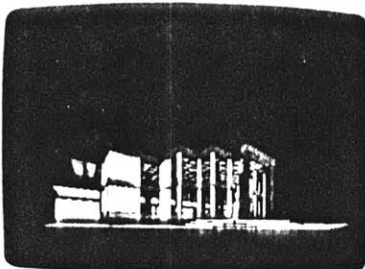
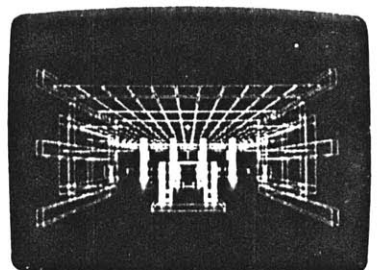
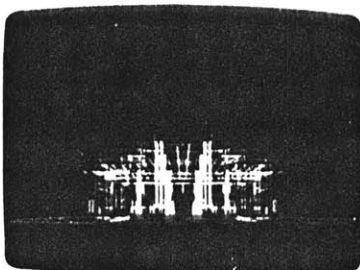
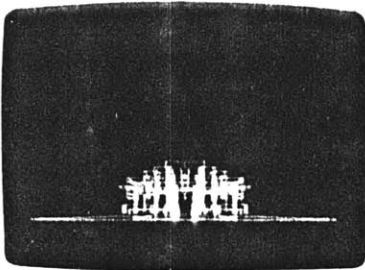
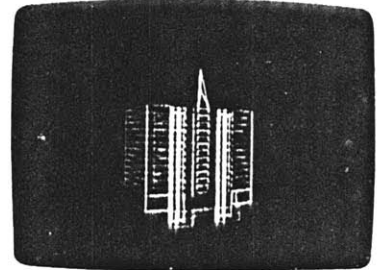
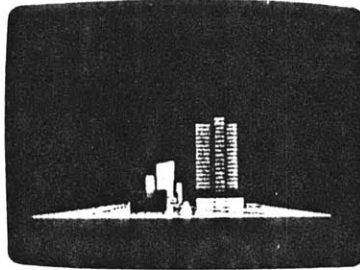
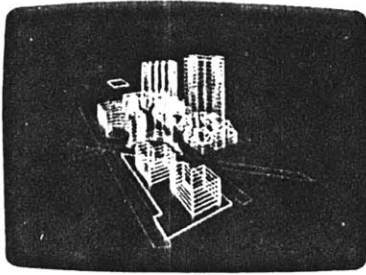




3-D Computer Visualization

Using today's computer capabilities, three-dimensional images of any project can be viewed at any stage of the design development stage. These are generated from the two-dimensional orthographic plans. Using the two-dimensional mode, room outlines and detailed modules are used to investigate alternative schematic options. The final schematic design becomes a detailed drawing by substituting outline modules with detailed modules.

A three-dimensional visualization can be generated from these two-dimensional plans. The viewing height and angle can be adjusted to show any perspective. Three-dimensional modeling is now possible by generating wire frame images and enhancing them with the hidden line removal mode, and surface shading can be added. Instant pan-and-zoom features bring detailed design elements up close for examination. This is a totally new way to communicate your design ideas. For client presentations the dynamic movement of the computer-generated images makes an even more effective simulation of the space than the individual still frames.



Computer Wall Painting

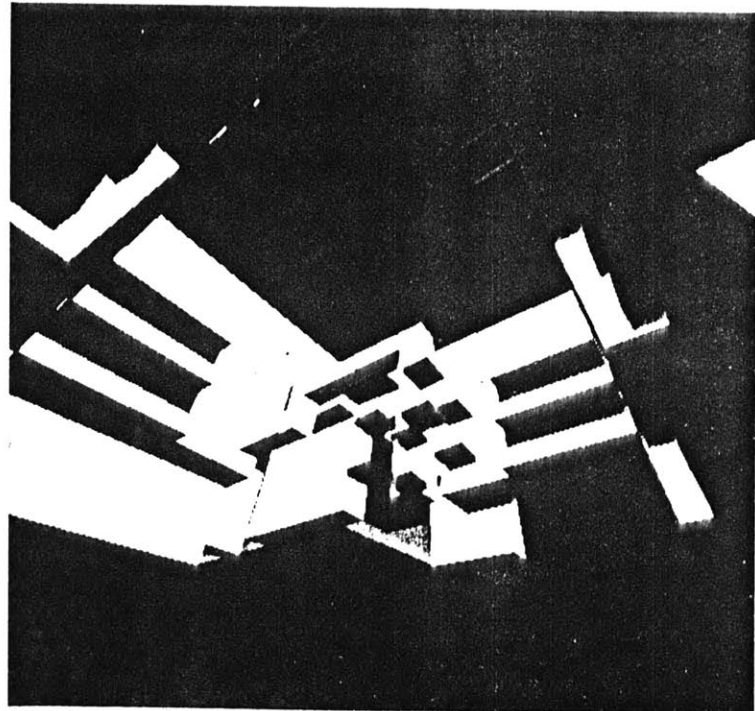
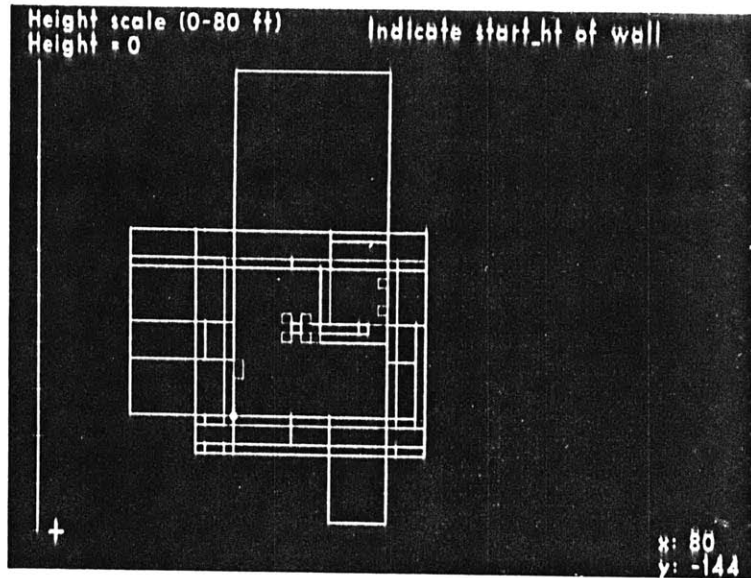
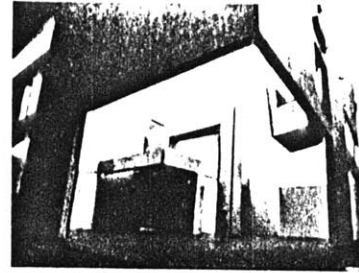
Architects work in three dimensions. In general they draw a plan or draw a perspective and finally build a model and photograph it. The computer allows you to generate, from the very beginning, a three-dimensional database with not only the thickness of material but the extension in three dimensions.

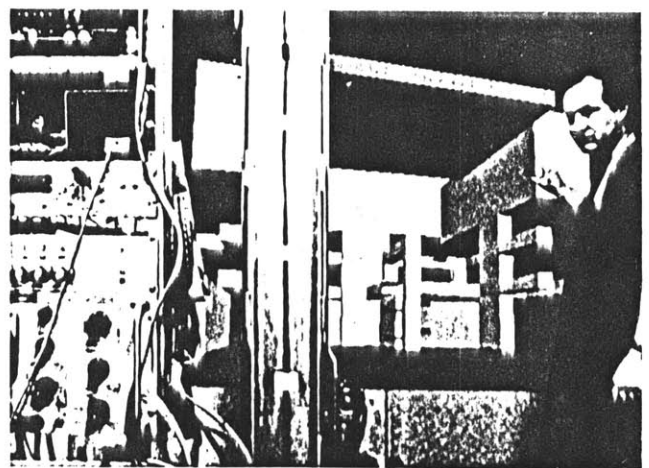
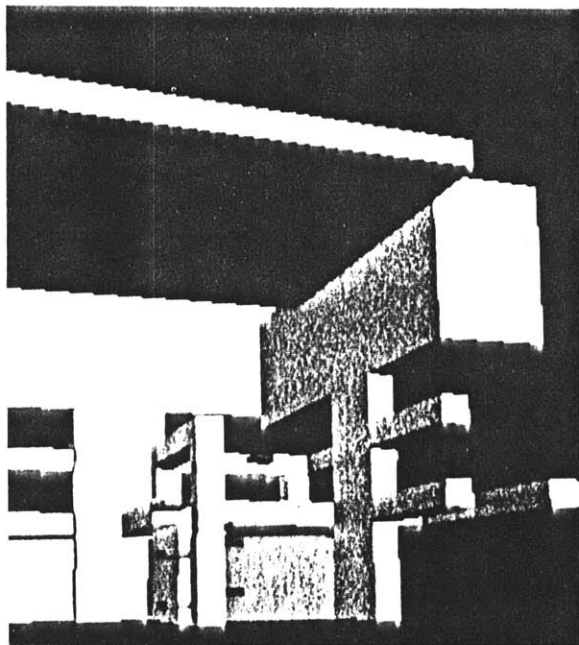
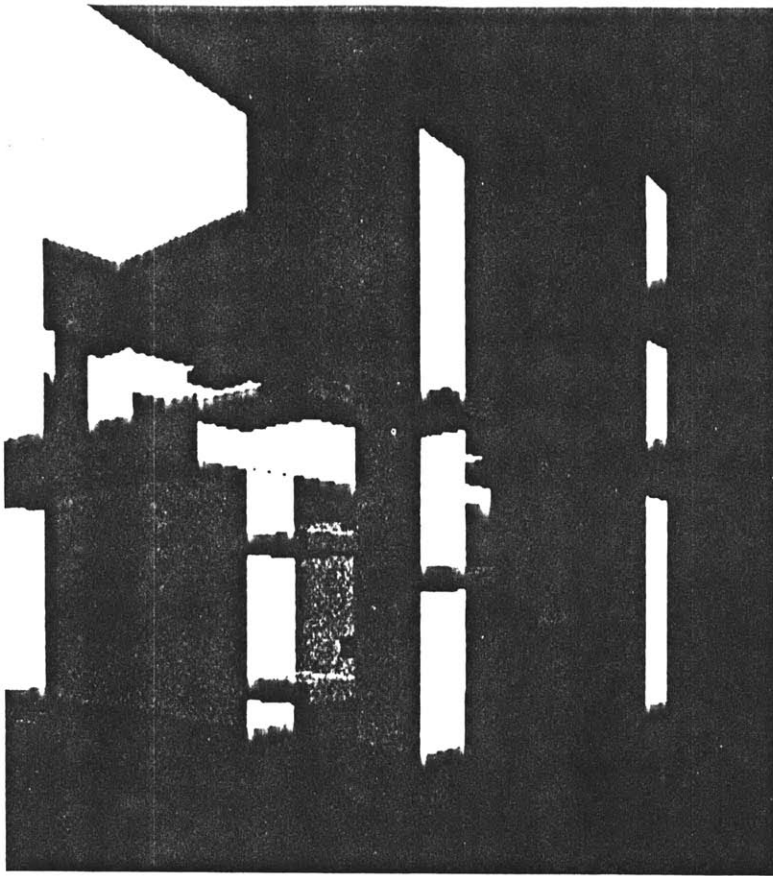
Just as you would build a model with little blocks, you're able to build with electronic volumes: This example shows the comparison of a rough working model and the equivalent electronic model.

This was in a very early stage of three-dimensional visualization, but it shows that any shapes you can present with a working model can also be presented by computer.

A comparison is shown of a working model and an electronic model on a CRT using the three-dimensional database.

On the right is a device developed at M.I.T.'s Visual Language Workshop. It is a large-scale plotter, which allows a plot using a spray-painting method on large surfaces, a plot of colored computer data. This could become a major influence on certain architectural simulations. With a large-scale plotter it would be possible to generate the facade on a computer and previsualize it in full scale before it is built.





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